# CHEMISTRY FOR INDIAN SCHOOLS

FOR STANDARDS IX & X.

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# INTRODUCTION.

THE following are an attempt at easy practical lessons for Indian Schoolboys. To go through the course once will need from seventy to one hundred hour's work, and this should be so arranged that the practical class is of two hours' duration. Students will then in nearly every case be able to either complete their experiments or leave their apparatus ready for work so that the experiment can be completed in the following lesson.

The attention of teachers is specially directed to the importance of well-kept laboratory note books. In these a detailed account of all experimental work must be written by the students as the work proceeds. "Fair copies" should never be permitted.

Mistakes should be pointed out by the instructor and rectified by the pupil. Failure in an experiment should always be made the occasion for deducing the *cause* of failure and faithfully recorded. Laboratory note books should be kept by the instructor and handed out at the beginning of a class. They will be inspected when possible by departmental officers, and invariably by examiners.

## CONTENTS.

# CHEMISTRY FOR INDIAN SCHOOLS.

## I.—APPARATUS. (1)

In classes VII and VIII, you have seen many chemical experiments. Some of these experiments you have helped to perform; others you have only watched.

Experiments in Chemistry are valuable for two reasons. The first reason is that each experiment teaches some fact about the substances with which it is made. The second reason why an experiment is valuable is that it teaches students how to use and make apparatus, and how to use their hands and eyes properly and well.

In the present course each boy must perform all the experiments for himself. Nearly all the great discoveries in chemistry have been made by chemists who used simple apparatus which they made for themselves, so you must not think that because your laboratory is not a large and grand one, or because your apparatus is homely and simple, you cannot perform your experiments properly. That would be a great mistake.

**To cut glass tubing.**—Take a sharp triangular file; hold the glass tube flat on the table, and with one edge of the file make a scratch on the tube. This should be done by drawing the file across the tube *once*, pressing gently with the file at the same time.

Now pick up the piece of tubing. You will find that the file has made a little nick, where it scratched the glass. A little of the glass has been rubbed away. Hold the tube with the scratch away from you and with your thumbs towards your body as shown in the illustration.

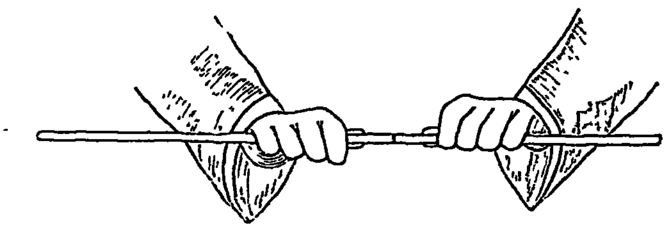


Fig. 1.

Gently push the tube with the thumbs and pull with the hands so as to open the scratch wider, as if you were trying to break the glass very much in the same way as you would break a stick. The tube will break quite neatly and cleanly at the scratch.

**To round the edge of a glass tube.**—Light your spirit lamp and hold one of the pieces of glass which you have cut so that one end is in the flame. Do not hold it too low in the flame. The hottest

part of the flame is near the outside edge or at the top, and that is the part in which your glass should be heated. Turn the tube round and round slowly as you heat it. You will find that in a minute or two it begins to get red-hot, and to colour the flame of the spirit lamp yellow. Heat it for a minute

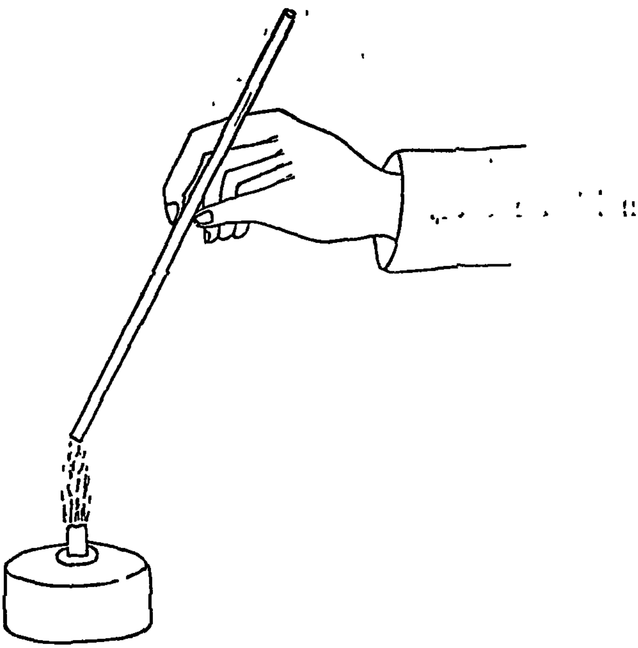


Fig. 2.

longer, then remove it from the flame and allow it to cool slowly. When it is cool, compare the part you have heated with the end of a tube which has not been heated. The former has a smooth, round edge, but the latter has a rough, sharp edge which might cut any rubber tube into which it was forced.

After cutting off a piece of glass tubing to use, you should always round the edges as described above. The rough edge is slightly melted and becomes smooth.

### I.—APPARATUS. (2)

**To bore a cork.**—To make a hole in a cork, a special tool is used which really is a hollow brass or steel tube. This is called a cork-borer.

These are generally made so that several fit one inside another.

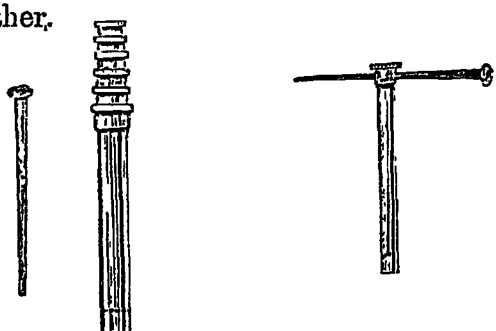


Fig 3.

Now suppose you wish to fit your glass tube whose edges you have just rounded into a cork. Lay the tube down on a flat table and place close beside it a cork-borer which seems about the same diameter. Now compare them carefully. If the cork-borer is wider than the tube, you must take another one. The cork-borer must always be exactly the same bore as the tube or just a little

smaller in bore. If it is wider, the tube would be loose in the cork and not air-tight.

When you have selected the right cork-borer, you must sharpen it with a file. This you do by gently rubbing round the edge of the borer till it is sharp. If the edges get bent inwards, they must be forced out again by putting a conical wedge of iron or brass in from the cutting side of the borer and turning it round and round with gentle pressure till the edges are circular again.

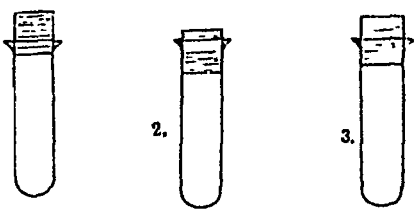
It is very important for the cork-borer to be sharp and circular.

You have now selected the right borer and sharpened it. The next thing is to bore a hole in the cork. Some cork-borers have handles, but most have a little steel rod which passes through a hole at the top of the borer. This rod should always be inserted before boring. It then acts instead of a handle. Take the cork in your left hand and the cork-borer in the right one. Begin to bore a hole in the middle of the cork by pressing on the borer and turning round at the same time. Be very careful to see that the borer is kept perpendicular to the cork or else the hole will not be straight. When you have bored three-quarters of the way through the cork, remove the borer. Very likely a little cylinder of cork will come away inside the

borer, and if so you must remove this by pushing the rod through the borer. Then turn the cork round and begin to bore from the other end to meet the hole you have made. This prevents the cork from being torn at the ends as it might be if the borer was pushed right through.

**To soften a cork.**—Corks are generally hard. If you try to fit one into a wide tube or flask, you will find that you have to use considerable force to make it fit properly, especially if you take a cork of the right size. A cork can very easily be softened, and a cork which seems too big to fit the tube before it is softened, often is just right after it has been softened.

Take a tube and a new cork which is just too large to fit the tube properly, that is, a cork whose narrow end will just go into the tube, but which will not go half its length into the tube. Then roll the cork under your foot on the floor for a few




1 and 2 badly fitting corks 3 well fitting cork.

Fig. 4.

seconds pressing with your foot as you roll it. You will find that the cork becomes much softer, and that after being rolled it will fit the tube properly.

**Fitting a tube into a cork.**—Before you bore the cork for the glass tube you must always soften the cork. If you tried to soften it after boring it, you would be sure to split or break the cork. When you have bored the cork, you must always be sure to round off the edges of the glass tube by melting in the flame as already described. Then take the tube in one hand and the cork in the other and twist the tube round and round, gently pressing it into the cork at the same time.

The tube must fit quite tightly into the cork, but if your hole is too small, it may be enlarged a little by gently turning a round file in the hole till it is large enough.

If your hole is rather small and you have not carefully rounded the edges of the tube, the glass will tear the cork.

Now fit a cork into a test tube, softening it carefully. Then select a piece of glass tubing and fit up a piece of apparatus as in the figure.

Ascertain whether your apparatus is air-tight by blowing down the glass tube. If there is any leak, find out where the leak is, and fit another cork up properly. You must never try to stop up a leak by bits of paper or wax. Such work is slovenly and always unsatisfactory.

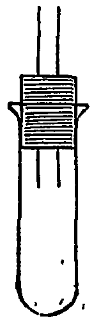


Fig. 5.

## III.—APPARATUS. (3)

**To bend a glass tube.**—When glass is heated it becomes soft. Take a piece of thin glass tubing and hold it in the flame of an ordinary spirit lamp, so that it becomes hot about three inches from the end. As it becomes red-hot, the glass softens and will bend through its own weight. If you try to bend it with your fingers you will find you can do so easily.

It is often necessary to bend tubes for chemical work, and there is a right way and a wrong way of doing so. The wrong way is the way you have just tried.

*First*, you must remember that *whenever* you heat a glass tube, or any vessel made of glass, you must apply the heat very gradually or else the glass will be liable to crack.

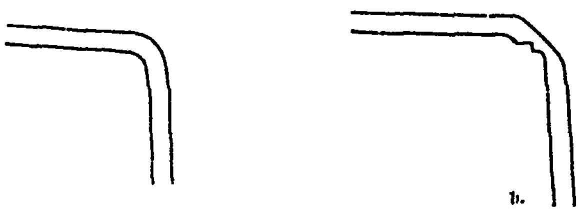



Fig 6

*Secondly*, when a tube is to be bent, it is necessary to heat as much of the glass as possible. If only a little is heated, the glass gets stretched on the outside of the bend and thickened on the inside.

A bend of that kind is always ready to break, if it is heated or dropped.

*Thirdly*, remember that the glass must be heated evenly and so you must turn the glass round and round in the flame while you are heating it. If it is not heated evenly when you bend it, the hot parts will stretch and bend, but the cooler parts will not do so so readily, and the bend is made of unequal thicknesses and so again it will be liable to break.

The best flame for bending a glass tube is a thin wide one. A spirit lamp with a flat wick about 2 inches wide does very well. Such a lamp can be made by any coppersmith. Hold the tube between the fingers and thumb of each hand and heat it in the middle. You must keep it revolving slowly by means of your fingers, all the time you are heating it, and always keep it turning in the same direction. When it is soft enough to bend easily, take it out of the flame and bend it slowly to a right angle. Then hold the bend over the flame for a few minutes, so that it will not cool too quickly. A good bend should look like fig. *a*. A bad bend looks like fig. *b*.

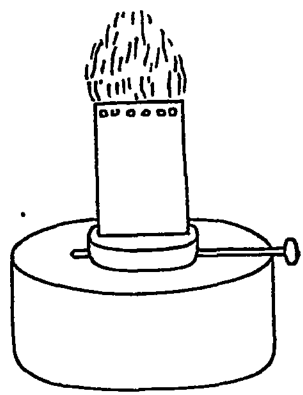


Fig. 7.

**To draw out glass tubing.**—Heat a piece of tubing in the ordinary lamp till it is quite soft; hold it just as if you were going to heat it for bending and keep it revolving continually. When soft remove it from the flame and pull the two ends apart slowly. Keep a pull on the glass till it becomes quite hard.

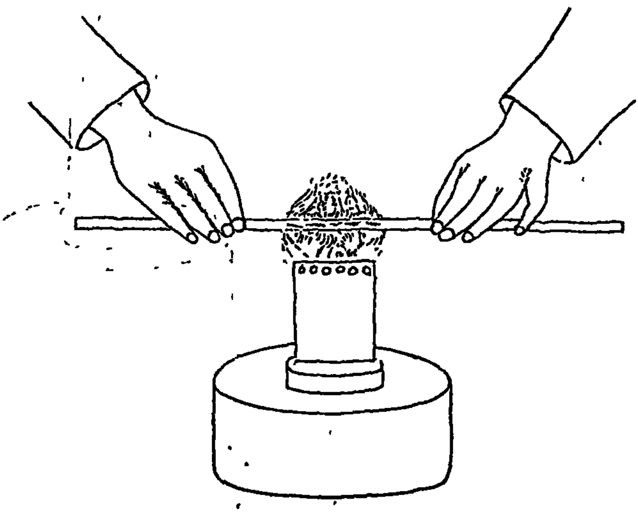


Fig. 8.

It will then appear as in the figure. Make a scratch in the middle of the thin drawn out portion and break the tube at that point. You will then

have two *jets.* If you pull too quickly the soft glass will become too thin and you will not be able to hold the tube rigid till the glass has become hard. You will then get jets which are of a bad shape because the hot glass will bend as in the

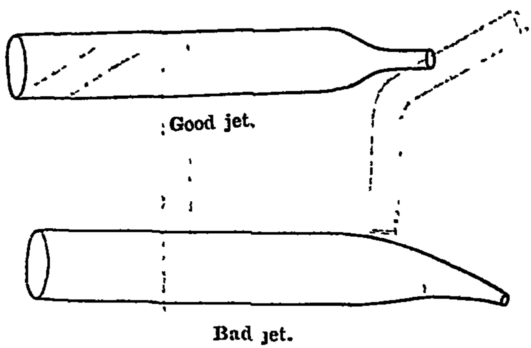


Fig. 9.

figure. The same will happen if the glass is heated unevenly.

## IV.—APPARATUS. (4)

**To make a wash bottle.**—Get any bottle of about 400 to 600 c. c. capacity with a round neck about three centimetres in diameter. Such bottles can be bought in any large bazaar. Those used to hold caustic soda and certain patent foods do very well. Then fit the bottle with a good, sound cork. In the cork bore two holes parallel to one another to take two glass tubes as previously directed. One of these tubes should be 15 c. m. long and

bent as in the figure (*a*), the other must be long enough to reach to the bottom of the bottle, pass through the cork and project about 10 c.m. above the cork. It should be bent as in the figure (*b*).

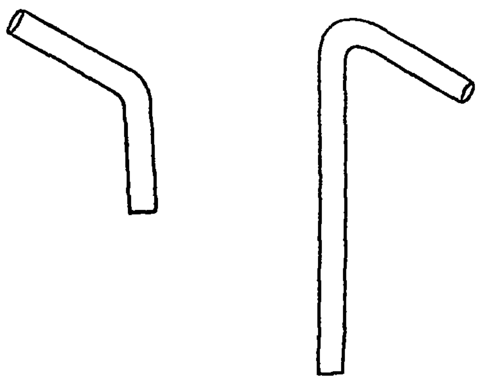


Fig. 10.

When you have bent this last tube, cut off from the short end about 5 centimetres. Then round the ends of both tubes and fit up the apparatus as in fig. 11. At the end of the long tube you must fasten one of your jets by means of a short bit of rubber tubing. The glass tube must fit into this quite tightly.

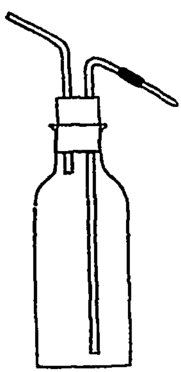


Fig. 11.

This is called a *wash bottle.* Blow into the short limb and a jet

of water will be blown out from the longer limb. This is used for washing many things and for delivering small quantities of water. Since the jet can be moved about, it is very useful, because the water can easily be blown out in any direction.

If a larger quantity of water is required, the bottle is inverted and water poured out at the short tube.

**To make a tripod stand.**—Take some stout iron wire and cut it into 3 lengths each 42 centimetres long. Bend each of these lengths as shown in the figure so that each leg is 16 centimetres long.

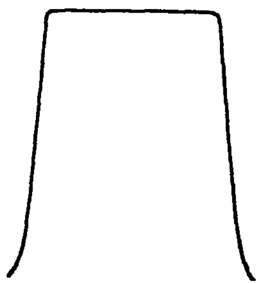


Fig. 12.

To bend the wire, you must use pliers. Hold the wire tightly in the pliers at the place where you wish to bend it and then bend the wire with your free hand.

Then fasten these three pieces of wire together by means of soft, copper wire wound round the legs, and cut off the ends at the bottom if they are uneven, or file them level by means of a file

To fasten off the copper wire, you must leave 2 centimetres of one end free when you begin to wind and when you have wound 5 or 6 turns of wire, cut off all but 2 centimetres from the long end. Now, take the two short ends and twist them together by means of the pliers. See figures 13 and 14 If you put 3 of these little coils round each pair of legs, one near the top, one in the middle and one at the bottom, the tripod shou be quite firm.

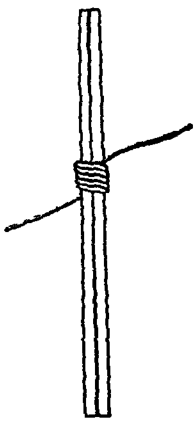


Fig 13.

Fig. 14.

If you prefer it, you may wind the wire right up the legs from the bottom to near the top, but in that case the winding wire will have to be started in a different manner. You must in this case lay the winding wire along the legs from the top to the bottom and begin to wind from the

bottom over the three wires, that is, over the two iron wires and over the copper wire itself. This is shewn in figure 15. When you have wound nearly to the top, finish off by twisting the two ends together with the pliers as before. This is a rather more difficult method of winding but it is neater and firmer than the first method; in this method, the winding wire may be quite thin.

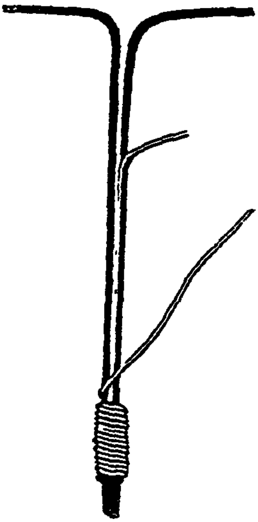


Fig 15.

## V.—CHEMICAL ACTION. (1)

The action of physical forces such as heat, light, the force of gravity, magnetism and electricity is different in one important way from chemical action. All these physical forces can act at a distance. Thus we feel the heat of the sun and see its light, although we are a very long way from it: the earth attracts other bodies which are far from it, and so also with the forces of magnetism and electricity.

Chemical action is very different. It cannot take place between two substances which do not

actually touch one another. Even when two solid substances do touch one another we generally find that no chemical action takes place, and that we have either to dissolve them or to apply some kind of energy to make any action take place. Let us take a few examples.

**Solution.**—First take some dry *tutia* or sulphate of copper and mix it as well as you can in a mortar with some dry carbonate of soda. You find nothing happens. But change the dry powders into solutions, make each solution in a separate tube, and mix the solutions. You find that the clear liquids alter in appearance; a solid is formed in the tube. Chemical action has taken place.

Perform a similar experiment with carbonate of soda and tartaric acid. What evidence have you that chemical change occurs?

Here, dissolving the substances helps them to act on each other chemically and form new substances. *When substances are dissolved they can always* act upon one another much more readily because they can always be brought actually together. In the solid state, it is very difficult to bring even a few particles together at the same time. One reason is because there is nearly always a thin layer of air surrounding them. In a solution, this is not the case.

**Energy.**—A second way in which solid substances may be made to react is by giving to them energy. The energy may be given by heating them, by allowing light to fall upon them, by the action of electricity, or by a blow with some other body.

(1) Chemical action produced by heat.—Mix some sulphur and copper turning. No action takes place. Now heat some of the mixture on an iron tray. A greenish-black mass is formed quite different from sulphur or copper. Chemical action has taken place.

(2) Chemical action produced by light.—Take a crystal of Nitrate of Silver and dissolve it in 2 c.c. of water. Add to this a few drops of strong salt solution in a darkened room. Notice that a new white substance is formed in the tube. Keep this in the dark and no further change takes place. Hold the tube in sunlight for a few minutes and the white solid becomes black. Light brings about chemical change.

(3) Chemical action produced by a blow.—This is what happens whenever a gun or cannon is fired. Boys generally like explosions, so here is an experiment you may try.

Powder a little sulphur in a mortar and place the powdered sulphur on a sheet of paper. Clean the mortar and powder a few crystals of potassium

chlorate. Put this also on a sheet of paper. Now mix equal parts of the two by gently stirring them together on the paper. Put as much of the mixture as will cover a two-anna bit on a stone on the floor and hit it a smart blow with a hammer; you will have an *explosion.*

Chemical action may be brought about by a blow.

## VI.—CHEMICAL ACTION. (2)

**What happens when a candle burns.**—You know that if you take a piece of candle and light it in an open place free from draughts, it will continue to burn until it has all burned away.

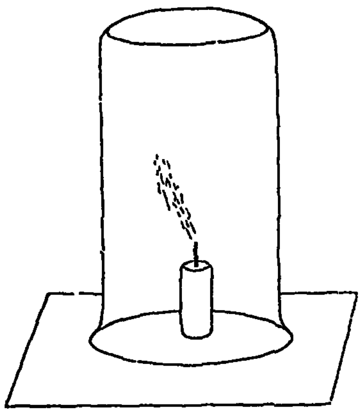


Fig 16

But take a small candle about an inch long, fix it on a smooth card or piece of wood or glass, place this on the table, light it and invert a beaker or gas jar, or even a large drinking glass over it. The candle will continue to burn steadily for a few seconds, then it will begin to flicker and give out

some smoke and finally it will go out and cease to burn at all. Now since a candle will continue to burn in an open space till it is all used up, the reason why it does not burn under the glass vessel must be that the space is closed up. In other words, we may say that fresh air cannot get to the candle when it is under the glass, but that fresh air can get to it when it burns in an open space.

We must find out then whether the air under the glass is changed in any way when a candle burns.

Take two similar gas jars, over each of them put a piece of ground glass[c] on which a little grease has been rubbed. This is simply to close the mouth of the jar when you shake it towards the end of the experiment.

Now, you must take what is called a deflagrating spoon and fasten a small piece of candle into the spoon.

A deflagrating spoon is simply a long wire with a little cup or spoon at one end of it. This wire passes through a cork and the cork is fixed in a plate of tin which is large enough to cover the mouth of the gas jar.

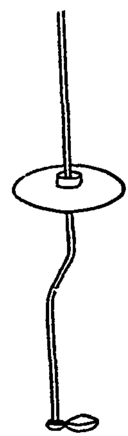


Fig. 17.

[c] See appendix.

Light the candle and lower it into one of the gas jars. Note what happens. Just as before, the candle first burns brightly, then flickers, and then is extinguished.

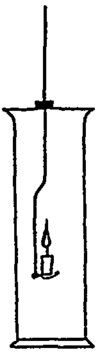


Fig 18.

Take the candle out carefully and quickly cover the jar with the glass plate. Light the candle again and lower it into the same jar. It is extinguished at once. Obviously the air in this jar has become different from the air of the room.

Remove the candle again and replace the glass plate. Look at the air in the two jars. There is no difference so far as you can *see*. This is where the science of chemistry can help us. Into each of the two jars pour a little lime-water. First shake up the jar containing pure air. What happens? Then shake up the jar in which the candle has been burning and note what happens. From these experiments it is quite clear that some chemical change has taken place in the air in which the candle has burned. We must find out what the change is due to.

Let us see what happens when sulphur burns in air. If you set fire to a piece of sulphur it will burn away till it disappears completely. But if you put a piece of sulphur in a deflagrating spoon,

set fire to it and lower it into a gas jar, the sulphur, like the candle, will soon be extinguished. Now the air in which sulphur has burned will not turn lime-water milky but if you pour a little blue litmus solution into the jar and shake it you will find the litmus solution is turned red. If you shake ordinary air with blue litmus solution it does not change the colour at all. So you see that when sulphur burns in air, the air becomes changed.

From these experiments you learn that when sulphur and a candle burn in air they alter the air. The air will no longer allow things to burn in it or "support combustion," and some new substances are formed in the air. When sulphur burns, the new substance turns blue litmus red, and when a candle burns the new substance turns lime-water milky.

How can this be explained? Possibly when things burn in air they give out some gas which extinguishes burning things, or possibly they take away from the air something which is absolutely necessary in order for things to burn. These are the only two possible explanations. Your next experiments will be to find out which explanation is correct.

## VII.—CHEMICAL ACTION. (3)

**The burning of Phosphorus**—Take a large gas jar and divide it into five equal parts by means of strips of paper pasted on the outside. If you paint each strip and the neighbouring glass with a little melted paraffin wax or bees wax, the strips will not be loosened by water when wetted.

Now, make a small circular piece of wood about 3 centimetres in diameter; in the middle of this cut a hole one centimetre in diameter. Instead of wood you may use a large cork.

Float this piece of wood in a chilumchi or basin of water. On the little floating ring of wood lay the lid of a porcelain crucible and on the crucible place a piece of phosphorus about the size of a grain of gram.

Phosphorus is dangerous stuff to handle. A small dish of water should be placed beside the bottle containing the phosphorus; then a piece of phosphorus is taken out by means of the tongs. This is put in the small dish of water and held there with the tongs while a piece of the required size is cut off by means of a sharp knife under the surface of the water. Then put back the large piece into the bottle. Place the small piece on a

bit of blotting paper and quickly dry it and then, again with the tongs, place it on the porcelain lid.

Light it by touching it with a hot wire, and over the floating lid insert the gas jar full of air.

Hold the jar down till the phosphorus ceases to burn and allow the jar to cool. When quite cool add water to, or remove water from, the basin till the level of water is the same in both the basin and the jar. Note the alteration in volume of the air in the jar. You will find that one-fifth of the air has disappeared. It has been used up by the burning phosphorus.

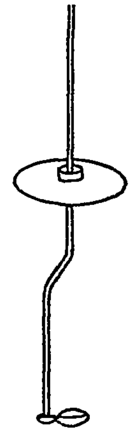


Fig. 19

Next you must find out whether the air in the jar will support combustion.

Slide a well greased ground glass plate under the mouth of the gas jar and remove it to the table placing it now mouth upwards.

Light a candle fixed to a deflagrating spoon, and remove the glass

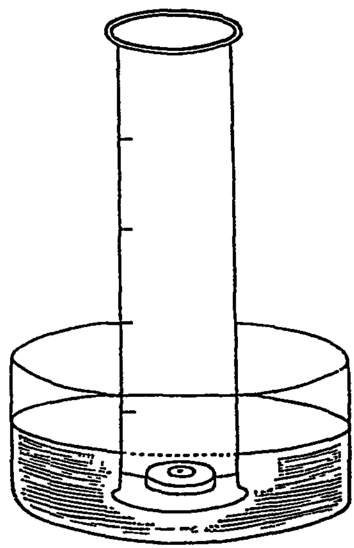


Fig. 20.

plate and introduce the burning candle into the jar. It is at once extinguished. The gas in the jar does **not** support combustion.

Pour a little blue litmus into the water in the jar. It is turned red.

**Deduction** When phosphorus burns in air part of the air is used up.

## VIII.—CHEMICAL ACTION. (4)

**What happens when iron burns.**—You may not know that iron can be made to burn, but such is the case. In ordinary air only iron which has been made into a very fine powder will burn and as you cannot make the powder for yourself you must take some from the stock provided for you.

Take the floating board and on it place a small tripod made from iron or copper wire. This should be quite small and can be made of fine wire twisted together as follows. Cut off three pieces of wire 10 centimetres long and twist the ends as in the figure.

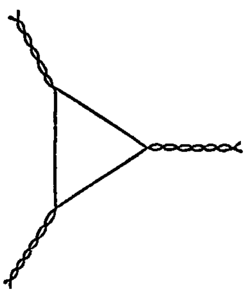


Fig 21

Then bend the twisted ends so as to make them into little legs. Place this on the floating board. Then take a piece of fine wire gauze and on to it shake out about

5 grams of iron powder. Place this on the tripod stand. Now light the powder by means of a wire with a little cotton wool wound round the end and soaked in spirit. When the iron begins to burn cover it with the gas jar in the previous experiment, and press the jar down to the bottom of the basin. When the iron ceases to burn put a weight on the top of the jar to hold it steady, and allow it to cool. This will take about half an hour ; at the end of that time adjust the level of the water as in the last experiment, and notice how much air has been used up. Again you will find that one-fifth of the air has been used up. Look at the iron powder. It has altered in appearance and has undergone some change.

**Deductions from these experiments on burning.**—We find that when substances burn in air which is enclosed in a jar, they are soon extinguished and that new substances are formed. We also find that both in the case of phosphorus and iron exactly one-fifth of the air is used up, and that substances will not burn in the remaining gas. We are now in a position to draw these conclusions :

**(1) When substances burn in air, they combine with some gas present in the air to form new substances.**

**(2)** **Air contains two kinds of gases, one which supports combustion, and one in which things cannot burn.**

**(3)** **The proportion of oxygen to nitrogen is 1 to 5 nearly.** *The former of these we call* **oxygen** and the latter we call **nitrogen**

## IX.—CHEMICAL ACTION. (5)

**Change of weight in burning.**—If, as we decided in the last lesson, burning things take something out of the air, they ought not to decrease in weight

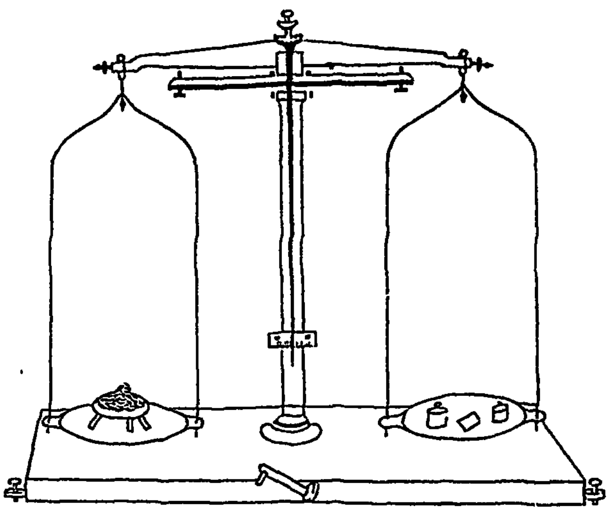


Fig 22

but to increase. Let us examine this statement. If a candle or any other substance, such as iron,

burns in a closed vessel, it is clear there will be no change in weight in the vessel. Nothing can get into it, and nothing can get out of it.

On the other hand, if we burn a candle in an open space it is quite clear that the candle loses weight and that a new gaseous substance is formed which we cannot easily weigh. We will consider the case of a candle in the next lesson. First let us see what happens when substances like iron burn in open air.

On the left-hand pan of a balance put a sheet of thin tin.

Take your little iron tripod and place it on this piece of tin. On the tripod put a piece of fine gauze and on to the gauze shake some "iron powder." Now carefully balance this by weights in the right-hand pan.

Set fire to the iron powder as before.

This will burn and as it burns some may drop into the pan, but that will not matter. You will see that the left-hand pan sinks slowly showing that the iron has steadily gained in weight by combining with the oxygen of the air. The new substance is called oxide of iron.

Another very good way of showing that a substance gains in weight when it burns is

by burning the substance magnesium. You will require a small pipe clay triangle which you can easily make for yourself, as follows :—

Cut 3 iron wires each about 20 c.m. long. From a clay pipe (the kind sold as "churchwardens" are best) break off three pieces from the stem each about 4 c. m. long. Pass one wire through each of these and then twist the ends together as in the figure. Place this on your tripod stand and heat in the spirit lamp flame for a few minutes. Allow it to cool and place on it a small porcelain crucible with its lid and heat these for a few minutes. In heating anything like a crucible remember to apply the heat gradually, by moving the lamp to and fro under the crucible till it has become hot. Then it can be raised to red-heat without danger of breaking.

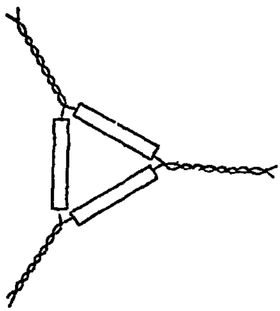


Fig 23

When the crucible is cold again, cut off about four or five inches of magnesium ribbon, and put this in the crucible, covering the latter with the lid, and weight it.

Next place the crucible on the pipe-clay triangle and heat the crucible with the lamp until the

magnesium begins to burn. Lift up the lid a little way from time to time until all the magnesium is burnt, but be careful not to let more smoke escape than is necessary. You must lift up the lid to allow fresh air to get to the magnesium or else the magnesium could not burn.

When the crucible is cool again, it is to be weighed. You will find an *increase* in weight, if the experiment has been carefully performed. Thus magnesium and iron both gain in weight when they burn in air. This supports our statement that burning substances combine with a gas present in the air to form new substances. We

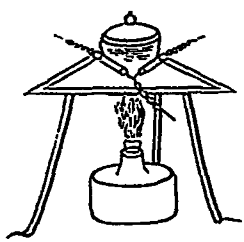


Fig. 24.

have called this gas oxygen. We call the new compounds oxides. When iron burns oxide of iron is formed, when magnesium burns oxide of magnesium is formed.

## X.—CHEMICAL ACTION. (6)

**A burning candle**—When magnesium burns a white smoke is formed and it is easy to see that this escapes when magnesium is burnt in air, but when a candle burns we cannot *see* that anything escapes. Therefore, when a candle burns away it would *seem* at first quite impossible for the candle to increase in weight. But we have already found when a candle burns it forms a gas which turns lime-water milky. You will now see that besides this gas, it forms a second substance.

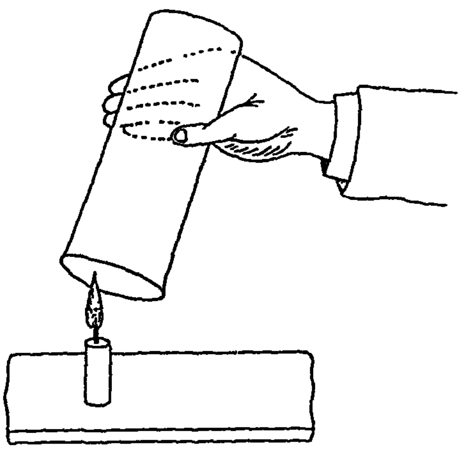


Fig. 25.

Over a burning candle hold a large cold empty beaker as shown in the figure. The beaker must

be dry as well as cold, but if it is warm the experiment will fail, so this should be done during the cold weather, if possible. If you cannot wait till the cold season, take a small glass flask and fill it with cold water and hold this above the candle flame.

You will find that drops of moisture condense and collect on the glass of the beaker or flask, as the case may be. If you could collect enough of this moisture you would find it to be water, so that water is the second substance formed when a candle burns.

To find out whether the substances formed by a burning candle are heavier than the candle itself or not, it will be necessary to catch this water vapour which condenses on cold glass, and the gas which turns lime-water milky. Fortunately there is a substance called caustic soda which will absorb both the water and the gas. Take a good large lamp chimney and cut out from some iron gauze a circular disc which will just slip down into the chimney. Hang this about half-way down the chimney by means of three wires bent into hooks at the ends. Each wire will then hook to the wire gauze at one end and the top of the chimney at the other end.

Now place a stout card on the left balance pan. On this place a small piece of candle. At each side

of the candle place two small blocks of wood about 2 centimetres high and 4 centimetres long and 2 centimetres wide. On these make the lamp chimney stand. On to the wire gauze put some pieces of caustic soda broken into little sticks about 2 centimetres long. These must not be packed tightly, because we want all the air from the burning candle to pass up the lamp chimney and it cannot do this if the caustic soda stops the way. Then carefully balance by weights in the right-hand pan.

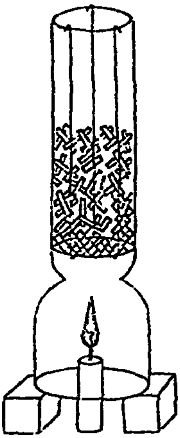


Fig. 26.

Now lift up the chimney, light the candle, replace the chimney and watch the balance. The pan on which the chimney rests will slowly sink. So that when a candle burns, the new substances which are formed are heavier than the candle was. You can understand that this must be the case, if you remember that burning means combining with oxygen. When a candle burns it combines with oxygen to form water and the gas which turns lime-water milky. These are heavier than the candle which is burned up to form them. They are really oxygen gas added to the candle. The gas which turns lime-water milky is called carbonic acid gas. You will learn more about it later on.

## XI.—CHEMICAL ACTION. (7)

Recapitulation.—You may now sum up what you have learned from your study of burning things.

*First.*—You have learned that when substances burn they are chemically changed and that new or different substances are formed. In other words, burning is a form of chemical combination.

*Secondly.*—You have learned that air contains two kinds of gases, one is oxygen, the active part of air, which supports combustion and combines with burning things; the other is nitrogen, the inactive part of air, which is left behind when things burn and does not support combustion.

*Thirdly.*—You have learned that when things burn in air they combine with the oxygen of the air, and that the new substance or substances formed are heavier than the original substance. We may express this by writing—

**A substance combined with oxygen is heavier than the original substance.**

Write down in your note books abstracts of the experiments which you performed to prove these three facts.

## XII.—THE CLAMP STAND OR RETORT STAND.

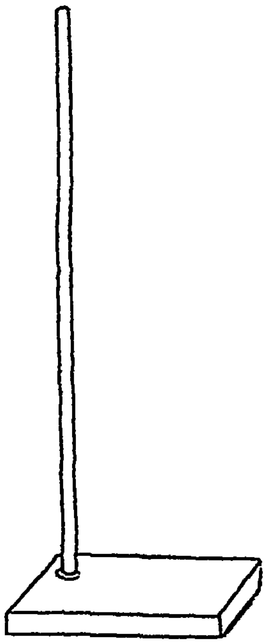


Fig 27.

Get the retort stand and unscrew all the parts and place them separate from one another. You must learn the names of these parts

First you have the **stand** itself which consists of a heavy iron **base**, and an iron **rod** or pillar. The rod generally screws into the base.

Next you have the **collars** or **boss-heads**.

Fig. 28.

These are iron collars which fit round the rod of the stand and can be fastened tightly to it by means of a screw. In the collar there is a second screw by means of which a clamp can be fastened to it.

The **clamp** consists of a rod of iron to which two jaws of iron are fixed. These jaws can be opened

or closed at will by means of a screw. The jaws are used for holding tubes, etc., which are generally made of glass and so they are lined with cork

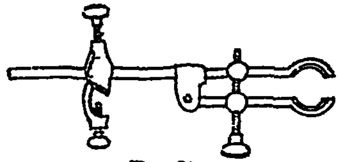


Fig. 29.

A retort stand also has one or more rings of iron which can be fastened on to the pillar by means of a collar on the ring itself. In the case of rings the collar is generally fixed on the ring and cannot be removed from it.

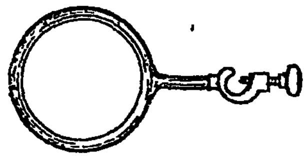


Fig 30.

Now you must learn how to use the retort stand. First fasten the ring on to the rod of the stand so that the base and ring are at opposite sides of the rod. Then fasten the boss-head to the pillar and the clamp to the boss-head so that the clamp too is at the opposite side to the base and is about 6 inches above the ring, while the ring is about eight inches from the table. Then put a copper water-bath on the ring or fill it with water. Is the whole apparatus steady? You will probably find that a slight tilt will upset it all. The method in which you have fixed up the stand is the wrong one.

It is most important that the stand should be able to support heavy pieces of apparatus and still remain stable.

See what you can do to make the stand stable. First turn the ring round so that it comes directly over the iron base, and then do the same with the clamp. Then again put the water-bath on the ring and see whether the whole is steady. You will find that it is. This is the way in which to fix up the parts of a retort-stand, so as to make it as firm as possible.

**The uses of a retort-stand.**—(1) As its name suggests one of the uses of a retort stand is to hold a retort. The condensing tube of the retort is placed between the jaws which are then screwed up so that they hold the retort fairly tightly. Care must be taken, however, not to have the jaws too tight or else as the glass expands through being heated, it may crack. A condenser may be held in the same way, but in both these cases a support should be given to the retort bulb or flask which is

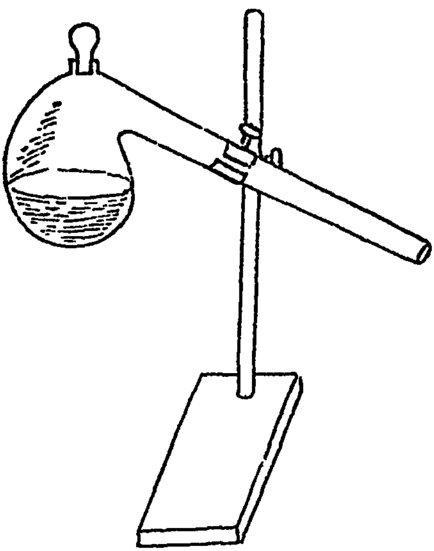


Fig. 31

to be heated, and the most convenient support is generally a tripod with a sand-bath.

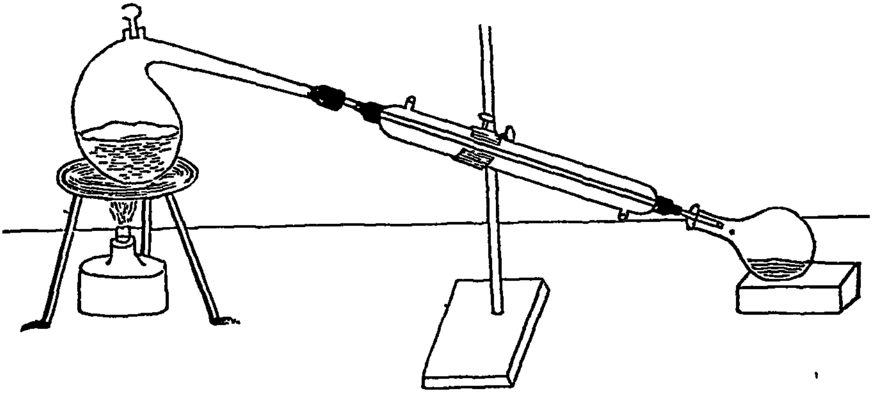


Fig. 32

(2) The ring of the retort stand may often be used in place of a tripod stand. The sand-bath or water-bath is placed on the ring. A great advantage of the retort stand when used in this way is that the jaws can then be used to hold the neck of a flask which is being heated on the sand-bath.

(3) The ring of the retort stand, or even the jaws make very good holders for funnels when filtering.

Set up a retort stand for use in these three ways.

## XIII --THE SPIRIT LAMP.

Every student needs a good spirit lamp for his experiments. A spirit lamp is a lamp in which methylated spirit or spirits of wine can be burnt. It *consists of three parts,* (1) *the container or reservoir,* (2) the wick tube, (3) the wick. It is a very good thing for the wick to have a cap or cover to keep it from getting dirty when the lamp is not in use. The best lamp for general use consists of a copper reservoir and tube. The reservoir must be of a good size, or it will get too hot from conducted heat. A convenient size is one about 8 or 9 c.m. in diameter and 6 c.m. high. The tube for the wick should be 1 c.m. in diameter and 2 to 3 c.m. above the level of the container.

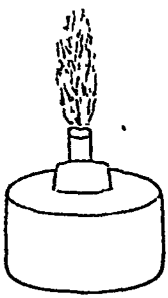


Fig 33.

The illustration gives the very simplest form. Such lamps can be made by any coppersmith at very little cost.

Students can easily make their own lamps from small wide-mouthed bottles as follows.

Get a 4 or 6 oz. bottle with a wide mouth and fit it with a good cork. Bore the cork and introduce a piece of glass tubing long enough to pass through the cork and project 2 c. m. at each side

of the cork. This tube should be 1 c. m. in diameter. Now get some soft cotton wick and pass it through the tube, just as if you were putting wick into a small oil lamp. Fill the bottle half full of spirit, and as soon as the wick has soaked up enough spirit, light the lamp. If you are not careful to round the edges of the glass tube very thoroughly the glass will crack and even when the glass has been rounded, sometimes it cracks and breaks. If you can get a copper or brass or tin tube instead of the glass, this lamp will serve all the ordinary purposes for which you require a spirit lamp. If you cannot get a metal tube, the glass tube may be protected by a bit of tin from an oil tin bent round and put inside the glass tube for a centimetre or so and projecting from it about half a centimetre.

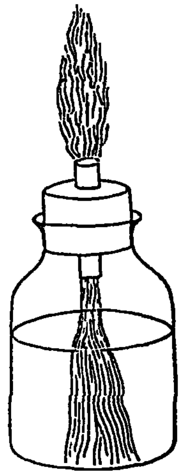


Fig. 31.

Notice the following points about a spirit lamp. First, the wick hardly burns away at all. The spirit is soaked up by the wick and it is the spirit which burns.

Secondly, the flame is blue—or non-luminous. If you place a spirit lamp in sunshine you can hardly see whether it is burning or not. It is very

important in chemical operations to have a non-luminous flame. Luminous flames always give smoke, and in boiling flasks and tubes and in heating other things, you must keep them as clean as possible, so that a smoky flame is always to be avoided.

Thirdly, the flame is hot. Hold a platinum wire in the flame, it soon becomes red-hot. Glass will soften and melt in the flame of a good spirit lamp.

Remember that a spirit lamp must be kept as clean as possible, and the wick should be covered by a cap, partly to keep it clean, partly to keep the spirit from evaporating, and partly to keep the wick from absorbing moisture from the air in wet weather.

Spirit for the lamp should always be kept in well-corked bottles. It too absorbs moisture in wet weather and then it does not burn well.

## XIV.—OXYGEN. (1)

The active gas contained in air is also contained in all **oxides** and also in many other substances. It is very easy to get it from these without any mixture of nitrogen. You are to prepare some pure oxygen and examine its properties.

Get a hard glass tube, that is, a tube made from glass which does not readily melt. You will not be able to make this for yourself so you must get one ready-made. Into the tube put a little red oxide of mercury. Hold the tube near the open end by means of a test tube-holder. One of the best and simplest test tube-holders is made by folding up paper till it makes a strip about 15 c.m.

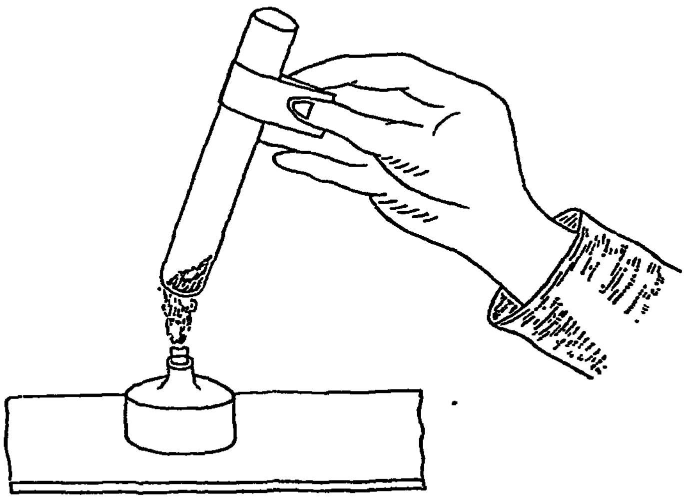


Fig 35.

long and 2 c.m. wide. It must be folded so as to give about 8 or 10 layers of paper, so for the original paper you would need a strip about 15 c.m. square.

This folded paper is held round the tube as in the figure.

Place beside you on the table a thin splinter of wood.

Heat the tube, shaking it gently in the flame. First the red oxide will turn black, then as you continue to heat it, a thin film like a mirror will condense on the upper part of the tube. Now light the splinter of wood and blow out the flame leaving a red glowing spot at the end of the splinter. Plunge this into the tube. Notice the result. As soon as the glowing splinter is placed in the tube it bursts into flame again, showing that the gas in the tube is no longer ordinary air.

Repeat this experiment heating the tube all the time. The new gas which rekindles the splinter is oxygen.

Then cool the tube and look at the part where the film has condensed ; rub the inside of the tube at this place with a small glass rod. A little globule or drop of mercury will form, which you can recognize. You now understand that when red oxide of mercury is heated it splits up into mercury and the gas oxygen.

Now fit the same tube with a bored cork into which you have fixed a small bent tube each arm of which is about 3 centimetres. By means of a small bit of rubber tubing fasten on to the free end of this a *delivery tube.* A delivery tube is a tube

used for collecting gases and is simply a long tube with one end slightly bent as in the figure.

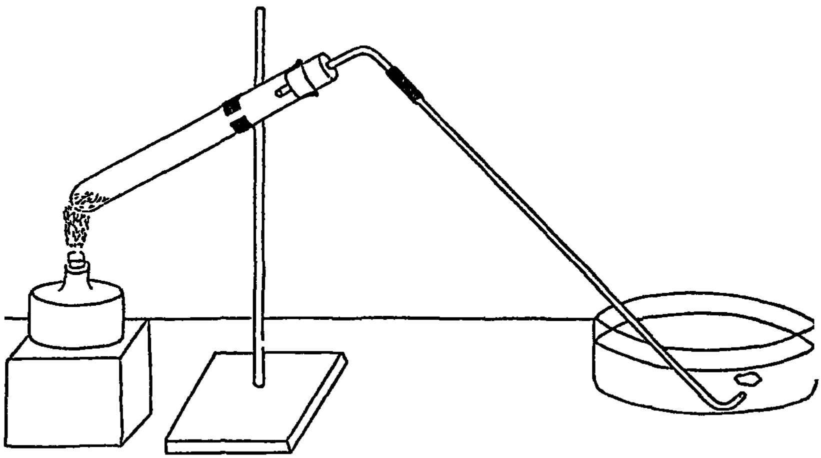


Fig 36

You will collect the oxygen by displacing water from a jar full of that substance in the following manner.

Put some red oxide into the tube and insert the cork.

Fix the tube in a clamp taking care not to screw up the clamp too tightly. Then fasten the straight end of the delivery tube to the bent tube in the cork and place the other end in a basin of water. Now if you heat the tube containing the oxide of mercury oxygen will be given off and will pass down the delivery tube and bubble up through the water.

Remove the delivery tube from the water and then stop heating the oxide of mercury. If you stop heating before you remove the delivery tube the gas in the heated tube will cool and as it cools will suck up water. If the water is sucked into the hot tube it will break it.

Now fill some test tubes with water and place your thumb over the end of one so as to close it completely. Then invert the tube and place your thumb under the water in the basin. Remove your thumb and you will have a tube full of water with the open end under the surface of the water in the basin. Put the delivery tube under the open mouth of a tube, and again heat the red oxide of mercury. Soon bubbles of gas will rise in the tube and fill it.

Collect two or three tubes of the gas in this way. Until you are ready to use them you may either hold them inverted in water, or you may put a cork into the open end, but you must do this under water.

The first tube which you collect will contain some air because the tube which you heated was full of air to start with. As the oxygen was given up by the mercuric oxide, it drove out the air and some of the air has passed into your collecting tube.

Notice that oxygen gas looks like ordinary air. It has no smell and no colour. See whether the

oxygen which you have collected will rekindle a glowing splinter of wood.

The method by which we have collected the oxygen is called "displacement of water." There are two reasons for collecting oxygen gas in this way.

The first is that oxygen is colourless and so if we passed a stream of oxygen into a jar of air, we could not see when it was full of oxygen. The second reason is that since gases can flow in all directions, some air would flow into the jar and some oxygen flow out, and we should need a special kind of apparatus to fill the jar so that no air was left in it.

### XV.—OXYGEN. (2)

To make large quantities of oxygen you would need a great deal of red oxide of mercury and a great deal of time. There is another way of making oxygen which is easier.

Chlorate of potassium like oxide of mercury, contains a large amount of oxygen. Take a few crystals and heat them in a test tube. The crystals melt, and if you continue to heat them strongly they seem to boil.

The chlorate of potassium is then breaking up or decomposing and giving off oxygen gas. See whether the gas evolved does not rekindle a

glowing splinter just like the gas evolved when oxide of mercury is heated.

Your test tube will soon be quite spoiled because you have had to heat it so strongly that the glass has partly melted, and so no doubt you think that this method is not a very good one.

Fortunately if we mix potassium chlorate with another substance called black oxide of manganese, oxygen is evolved at a very much lower temperature and the glass will not melt. Since glass always is liable to break unless it is very carefully heated, oxygen is generally made in copper flasks or tubes.

If you have a copper flask or tube (these can be made in any large bazaar) fit it with a cork and delivery tube as in the figure.

Then mix chlorate of potash with some powdered black oxide of manganese till the mixture is black and introduce about an ounce of this into the flask. Arrange a basin for collecting the gas by displacement of water, and fill several jars or wide-mouthed bottles with water and invert them in the basin.

To do this you must fill the jar up to the brim with water and then slide over the mouth a ground glass plate which has been greased with a mixture of paraffin and vaseline melted together, or with ordinary fat.

When the plate closes up the mouth of the jar, turn the jar* upside down and put it mouth downwards in the basin of water and slide the plate away again You will then have a jar of water inverted in the basin.

It is very convenient to have a little shelf on which to let the jars stand when the gas is being collected. These can be made of baked clay and should be large enough to let a jar stand on them, and about an inch high. They are moulded so that the delivery tube fits into a slit in the stand as in the figure.

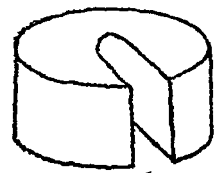


Fig. 37.

If you have not got one ready baked, you can make one of clay and bake it for yourself. Place a jar on this stand and put the end of the delivery tube under the jar; then heat the flask and collect 5 or 6 bottles of oxygen gas. You should have all your

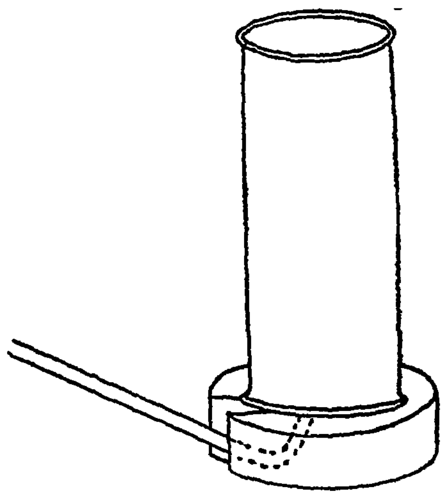


Fig. 38.

* If a bottle is used for collecting gas, the mouth should be wide and should be *ground* by rubbing on a flat stone with sand and water The use of this grinding is to make the ground glass plate fit quite closely to the mouth of the bottle

bottles ready inverted in the water before you begin to heat. As soon as one jar is full slide the greased plate under its mouth, holding the jar in the right hand and the plate in the left. Then remove it from the basin and put it on the table, keeping the plate over the mouth till you are ready to use it.

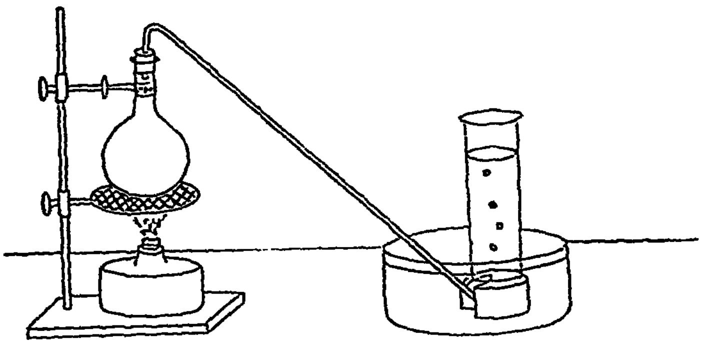


Fig. 39

When you have collected enough oxygen, remove the delivery tube from the water and then extinguish the lamp. You must always remove the delivery tube first; if you do not, the gas in the flask will cool and contract and suck up water into the flask. If the flask is a glass one, it will break at once; if it is a copper one, steam will be formed rapidly and will perhaps blow out the cork and delivery tube with explosive violence.

Oxygen made in this way often has a white cloudy appearance. This is due to small particles of the chlorate which are carried over. If the gas is allowed to stand over water for a few minutes the haziness will disappear.

If it is necessary to keep the oxygen till another day, it is best to keep the jars standing mouth downwards in water. Oxygen is only very little soluble in water and if the mouths of the jars are under water air cannot pass and mix with the oxygen.

## XVI.—OXYGEN. (3)

When you have collected several jars of oxygen you can examine the properties of the gas more completely than you have done already. You have already noted down its colour, smell and taste, and that it rekindles a glowing splinter. Now perform the following experiments :—

1. Take a piece of wire and fasten it round a piece of charcoal about the size of one cubic centimetre. Heat the charcoal until it is red-hot and then lower it into a jar of oxygen gas. Take care that the fiercely burning charcoal does not touch the sides of the jar, or it will crack them. You notice that the charcoal burns much more quickly

and brightly in the oxygen than it does in air. When it has ceased to burn, remove the charcoal and pour a little litmus-solution into the jar. Shake it well. Notice that the violet colour is changed to a deep red colour.

2. Place a small piece of sulphur in a deflagrating spoon. Set fire to it, and lower it into a jar full of oxygen. Note that sulphur burns much more brightly in oxygen than it does in air. When the sulphur ceases to burn, pour a little litmus solution as before and shake it up. Again the violet colour is changed to red.

3. Cut off a tiny bit of phosphorus about the size of a pea, as described in lesson VII. Put this in a deflagrating spoon by means of the tongs and set fire to it and lower it into a jar of oxygen. Do this in a dark room if possible and note the wonderful brilliance with which the phosphorus burns. Again shake with litmus solution and observe the change of colour from violet to red.

4. Take a piece of sodium from the bottle by means of the tongs. Sodium is not like phosphorus and if it is put into water it combines with it at once. Sodium is kept in kerosine or naphtha, and when you cut a piece off it must be done quickly and the sodium at once put back into the kerosine. Press the piece you have cut off between

blotting paper and place it in a *clean* deflagrating spoon. Ignite it by warming the spoon in the flame of a lamp. Notice that the sodium first melts and then catches fire. When the sodium has begun to burn in air lower it into a jar of oxygen. Notice that it burns much more brightly in oxygen than in air. Shake up with litmus solution. Now instead of the violet solution turning red, note down the change from violet to blue.

5. Fasten a small strip of magnesium ribbon or wire to a long iron wire. Ignite the magnesium and lower it into a jar of oxygen. Again notice the brilliance with which it burns. Shake up with litmus. Again there is a change from violet to blue.

6. Take a few pieces of *very* fine iron wire, each about 6 inches long, and twist them loosely together. Hold these twisted wires in the tongs and dip the free end into a little melted sulphur. Remove the wires, still holding them in the tongs and set fire to the sulphur, then lower the wires into the jar of oxygen. The wire will soon catch fire and begin to burn away, throwing out many bright sparks. Notice the brown substance which is formed at the bottom of the jar. Collect this and shake it up in a test tube full of water. It does not seem to dissolve. Shake it with a little litmus. There is no change in colour.

Now see what you have learned from these experiments and observations.

*First.* You find that all substances which burn in air burn more brightly in oxygen.

*Secondly.* You find that the new substances produced can be divided into three classes—

1. Those which turn litmus red.
2. Those which turn litmus blue.
3. Those which do not affect litmus at all.

In the next lesson you must consider these facts more closely and carefully.

## XVII.--OXIDES.

When substances combine with oxygen they form new substances called oxides. Thus sulphur forms oxide of sulphur, phosphorus forms oxide of phosphorus and so on.

Different oxides differ from one another very much. Some, such as oxide of iron and oxide of magnesium, and oxide of sodium, and oxide of manganese, and oxide of mercury, are solids. Others such as oxide of sulphur and oxide of carbon are gases. Other oxides are liquids.

They differ also in colour and appearance. Oxide of iron is brown, oxide of magnesium is

white, oxide of sodium is also white, oxide of manganese is black and oxide of mercury is red.

Some of these oxides readily dissolve in water, others dissolve slightly and some do not dissolve at all. Thus the oxides of sulphur and sodium dissolve readily, the oxide of magnesium slightly, and the oxides of iron, manganese and mercury are insoluble. The insoluble oxides do not affect litmus at all, but the soluble oxides have a peculiar action upon it. Some turn it red, and some turn it blue.

Let us examine this action a little more closely.

The oxides of sulphur, phosphorus and carbon turn litmus solution red.

The oxides of sodium and magnesium turn litmus solution blue.

Now sulphur, phosphorus and carbon are non-metallic substances, while sodium and magnesium are both metals.

At first it was thought that all oxides turned litmus red, but from a large number of experiments it was found not to be so, and that only soluble oxides of non-metals do, while soluble oxides of metals turn litmus blue.

Substances which turn litmus red are called acids. Those which turn litmus blue are called

**alkalis.** Those which do not affect litmus at all are called **neutral**

You may now state that **if the oxide of a metal dissolves in water it always forms an alkaline solution, while if the oxide of a non-metal dissolves in water it forms an acid solution.**

It was thought that all acids contained oxygen and the name oxygen was given to the active part of air because the word oxygen means *acid-former.* Now we know that this is not true, but the name oxygen has not been changed.

## XVIII.—OXYGEN:—SUMMARY.

You have now learned a good deal about oxygen. It is not enough to learn about a thing; you must also be able to express what you have learned fully, and clearly and briefly. Suppose that you were asked what you knew about a substance, what should you say? The proper way to answer such a question is to think of the following points:—

(1) Where does it come from, or occur?
(2) How is it made?
(3) What are its properties?
(4) What is it used for?

Let us say what we have learned about oxygen in that order.

*Occurrence.*—Oxygen is found in air of which it forms one-fifth part. It is also found in all oxides, and many other chemical compounds.

It also is one of the elements which make up water, as you will soon learn.

**Preparation.**—Oxygen can be made by heating several oxides, such as oxide of mercury or oxide of lead. These oxides then split up and oxygen is evolved. It is more easily prepared by heating potassium chlorate. The mixing of a little black oxide of manganese with the potassium chlorate makes the oxygen come off at much lower temperature. It is collected by displacement of water. (Describe and draw the apparatus).

**Properties.**—Oxygen is a colourless, odourless gas. It is a most powerful supporter of combustion and will rekindle a glowing splinter of wood making it burst into flame. All substances which will burn in air, will burn in oxygen with much greater brilliancy. Fine iron wire burns in oxygen to form iron oxide. All elements which burn in oxygen form oxides. The soluble oxides have different actions on litmus. Soluble oxides of metals turn red litmus blue and are called alkalis, but soluble oxides of non-metals turn blue litmus red and the solutions are called acids.

Oxygen is the active part of air. When things burn in air they combine with the oxygen and form the same compounds as when they burn in pure oxygen.

**Uses.**—Oxygen is necessary for burning. Nothing would burn in air if it were not for the oxygen which air contains. It is just as necessary for warming animals. All animals contain in their bodies a great deal of the element carbon and as they breathe, some of this carbon is changed into oxide of carbon, or as we shall call it later, carbonic acid gas. Now just as much heat is given out when a given mass of carbon is oxidized (changed into oxide) slowly, as when it burns quickly, and so this slow oxidation of the carbon keeps the body warm.

Of course this carbon in the body has to be replaced as it is used up. You can guess that it is replaced by the food you eat. Sugar and grain of all kinds contain large quantities of carbon. They can easily be made to burn in air or oxygen and then give off exactly the same gas as you get from burning charcoal. Charcoal, as you know, is nearly pure carbon.

You may say quite truly that all animals are slowly burning and that the oxygen in the air is necessary for this slow combustion.

## XIX.—ELEMENTS AND COMPOUNDS.

You have learnt that when substances burn they combine with oxygen and form new substances which are quite different from the substances in their original state. These are made up of oxygen and the substances which burn, and are called **oxides.** Thus when sulphur and phosphorus burn we get oxides of sulphur and phosphorus formed. Iron forms oxide of iron when it burns, sodium forms oxide of sodium and so on.

Now these oxides can all be made to break up into oxygen and the substance with which it is combined. In other words, all oxides can be split up into two or more *different substances* and all things which can be split up into two or more different substances are called **compounds.** All substances which cannot be split up into more than one simple substance are called **elements.** Thus you see that all oxides are compounds. They can be split up into oxygen and iron, or oxygen and sulphur, and so on as the case may be.

On the other hand, oxygen is an element. Oxygen cannot be split up into anything else but oxygen. Sulphur and iron and magnesium and sodium are all elements. They cannot be split up into simpler substances.

Many elements can combine together to form compounds. Thus, as you have already seen, all substances which burn in air form compounds with oxygen or oxides. Copper and iron can combine with sulphur. Take a few copper turnings and mix them with some powdered sulphur in a test tube and then heat the tube strongly, the sulphur will first melt and then it will begin to combine with the copper, making the copper glow with heat. When the tube is cool, break it up and examine the substance left in the tube. There is no copper left at all, but a greenish-black substance in its place. This is a new compound called sulphide of copper and it is made up of the two elements, sulphur and copper.

The following is a list of some of the most common elements :—

| | | | |
|---|---|---|---|
| **Hydrogen** | **Sulphur** | **Zinc** | **Phosphorus** |
| **Oxygen** | **Iron** | **Lead** | **Sodium** |
| **Nitrogen** | **Copper** | **Tin** | **Potassium** |
| **Chlorine** | **Antimony** | **Mercury** | |

The first five of these are non-metals, the rest are metals.

How can you prove that chlorate of potassium and oxide of mercury are compounds?

## XX.—RUSTING IN AIR.

**Rusting due to air.**—When iron is left in perfectly dry air it remains clean and bright, but in damp air it soon becomes covered with a layer of rust. You would perhaps conclude that the rusting is due to moisture and not to the air. Your next experiments will be to find out whether this is so.

Take two large test tubes and half fill them with water. Boil the water in one of them for a few minutes to drive away all the air dissolved in the water. Into this tube drop some iron filings and boil once more to get rid of all traces of air. Then pour a few drops of oil on to the surface of the water so as to form a layer over it which will prevent any air getting into the water.

Put this tube on one side. If the iron in this tube rusts, it *must* be due to water only, since no air can get to the iron.

Into the other tube drop some iron filings and do not boil the water or cover the water with oil but leave it open to the air. Put it beside the first tube and leave the two side by side for a day or two. In a few days you will find that the iron in the air-free water has not rusted, but that the filings in the tube open to air are covered with rust.

The rusting must then be due to air.

**What happens when iron rusts.**—Take a clean piece of tin cut from a kerosine tin. It should be about 10 c. m. square. On to this put some iron filings and weigh the whole *carefully, noting down* the weight in your note book.

Put the tin tray on a tripod stand and put the stand in some place where it will not be touched by other boys; then moisten the iron filings with a few drops of water. Take great care not to allow any of the filings to be moved from the tray, moisten the filings with water every day for two or three days. When a fair amount of rust has formed in the iron, take a spirit lamp and *gently* warm the tray until the filings are quite dry. Then weigh them and the tray as before.

Note down the weight after rusting. The weight after rusting is heavier than the weight before rusting.

You may conclude now that rusting is due to air and that **in rusting iron takes up something from the air and gains in weight.**

**The effect of rusting on air.**—If iron takes something from the air when it rusts you must next find out whether it takes away the active gas oxygen or the inactive gas. nitrogen.

Take a long glass tube about 40-50 c.m. long and 3-4 c.m. wide. If you cannot get a piece approximately this size a burette tube may be used, as described below.

Close up one end of the tube by means of an india-rubber cork or by a good ordinary cork which has been well soaked in melted paraffin wax. This cork must be absolutely air-tight. Divide the tube into five equal parts by means of strips of gummed paper. Invert it in a dish of water.

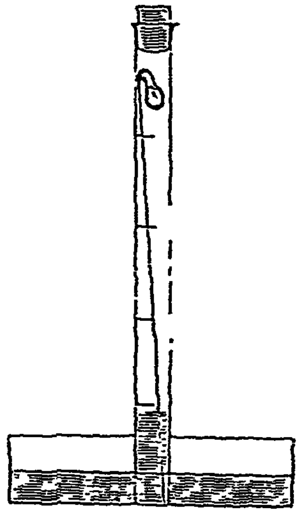


Fig. 40.

Now get some iron filings and boil them in a test tube with a little dilute caustic potash solution. The caustic potash cleans the iron and removes any grease from it. Then rinse them with clean water and tie them up in a little piece of muslin. Fasten this muslin bag to an iron wire which is about 2 or 3 centimetres less in length than the tube itself. Moisten the bag and filings with water and introduce the wire into the tube from the open end. The apparatus will then appear as in fig. 40.

Leave this to stand for several days and notice that the water rises in the tube to take the place

of the gas which combines with the iron to form rust. When the water rises no higher, it will have risen exactly one-fifth of the way up the tube, showing that one-fifth of the gas in air has been used up. Remove the tube keeping the mouth closed by a glass plate and invert it. The remaining gas extinguishes a burning match or candle. The gas used up must have been **oxygen.**

**Rusting must be combining with oxygen.**—You may call rusting slow combustion. Iron rust is iron oxide.

**Rusting of Phosphorus.**—Perform the same experiment using phosphorus in place of iron. It should be fastened in a little cage of iron gauze instead of muslin.

You will get a similar result. If you use a long gas jar in this experiment it will be easier to see that the gas left behind is not oxygen but nitrogen. But it will not be so easy to measure the amount of gas which combines with the phosphorus. The longer and narrower the tube, the more accurate the measurements will be.

## XXI.—WATER. (1)

You have now in your experiments made a study of burning and rusting and have found that air consists of two gases, oxygen and nitrogen. These are present in the proportion of one part of oxygen to four parts of nitrogen. You will learn later that these are mixed together and not combined. In other words, air is a mixture and not a chemical compound.

Now you will perform some experiments with water in order to find ~~out what water~~ consists of and to learn some of its properties.

Take a small piece of fine wire gauze, roll it round a pencil so as to make a hollow cylinder. Bend one end so as to close it. Then drop a piece of sodium about the size of a pea into the cylinder and close the other end.

Invert a test tube full of water in a basin and then drop the wire cage into the water and hold the tube over it.

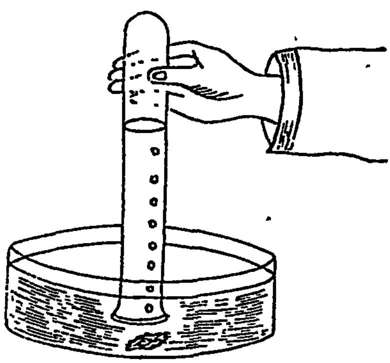


Fig 41.

Notice that some chemical action takes place between the sodium and the water and that a gas is

evolved which rises in small bubbles and displaces the water in the tube. When the tube is full or when the sodium is used up, put your thumb under the mouth of the tube to close it and remove it from the water.

Bring a lighted match near it and then remove your thumb and see whether the gas supports combustion. You will find that the gas burns itself with a pale blue flame. This is a new substance. The name given to it is **Hydrogen.**

Has this hydrogen come from the water or the sodium? Sodium is an element. It cannot be split up into any other substances, so you may be sure that the hydrogen came from the water. So one of the substances of which water is made up is a gas called Hydrogen.

To the water in the glass dish in which this hydrogen was made add a little litmus solution. It turns blue at once. Now you have already seen that oxide of sodium when dissolved in water turns litmus blue. It is quite possible, then, that here too we have got some oxide of sodium. If that is the case, water must contain both hydrogen and oxygen. The sodium combines with the oxygen and releases the hydrogen.

Your next experiment will show that this is true.

## XXII.—WATER. (2)

Water can be decomposed by many other metals as well as by sodium, as you will learn, but there is one way in which it can be decomposed in which no metal is used to combine with the oxygen. This method is decomposition by means of the electric current, and is called **electrolysis**.

For the decomposition of water by electricity you need a piece of apparatus called a **voltameter**. This you may make for yourself.

Take a large glass funnel and cut off the narrow tube about half an inch below the neck. Then fit the neck with a good cork, pushing it in from the wide part of the funnel. The cork should not be very long, but should fit well. About 1·5 c.m. is quite long enough.

Now by means of a red-hot needle make two holes through the cork at least a centimetre apart.

Fig. 42.

Take a piece of platinum foil about 3 centimetres long and 1·15 centimetres wide. In this prick

4 holes and through the holes thread a platinum wire about 10 centimetres long as shown in the figure. Do the same with a second piece of foil.

Now take your large needle, thread the free end of one platinum wire through the eye so that about 5 millimetres pass through it. Bend these 5 millimetres back close to the rest of the wire. Then push the needle through one of the holes you made in the cork and pull the wire through so that the platinum foil nearly reaches the cork.

Do the same with the other wire and foil and the other hole in the cork.

Your two pieces of foil should now be standing up in the middle of the funnel as in figure 43.

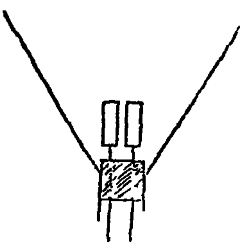


Fig. 43

Bend them a little outwards and then pour some melted paraffin wax into the funnel till the wax reaches just above the bottom of the foil.

Then when the wax is cooled the whole cork will be quite water-tight. The platinum plates are bent outwards to enable each to be covered by a test tube and they should be about 2 centimetres apart.

These plates are called electrodes.

The voltameter may now be placed in the ring of a retort stand.

*Now add 2 or 3 c.c. of sulphuric acid to a litre* of water. Fill the voltameter till the water is over the electrodes and fill two test tubes of equal size with the same acidulated water. Invert them in the usual way in the voltameter, and then carefully place one over each electrode.

Hold them in position by means of the clamps on the retort stand.

Next connect the platinum wires from the electrodes to the zinc and carbon plates of a good battery. A battery of 3 or 4 Grove's cells, or bichromate cells will do.

Bubbles of a gas will soon begin to rise in the two tubes, but in one tube twice as much gas will rise as in the other. When one tube is full the other will be half full.

Remove the tube which is full of gas putting your thumb

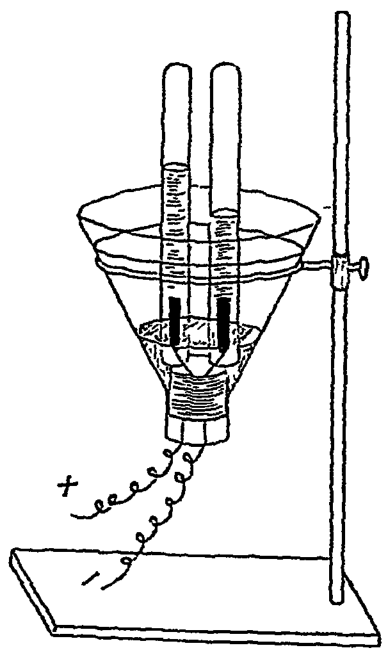



Fig. 44.

under the open end as usual. Bring it close to a spirit lamp and see whether it will burn. It at once takes fire and burns into a blue flame. This gas is hydrogen.

When the other tube is nearly full, remove it in the same way and put a glowing splinter into the gas. It is at once rekindled. This gas must be oxygen.

You may now conclude that water contains both oxygen and hydrogen, and that there is twice as much by volume of hydrogen as there is oxygen.

The question whether water contains anything else we shall answer in another lesson.

## XXIII.-HYDROGEN. (1)

You have already seen that hydrogen can be prepared by the action of the metal sodium upon water. It can also be prepared by the action of many other metals upon water, or upon the vapour of water which we call steam.

**Action of steam on iron.**—Iron does not combine with oxygen so readily as sodium does, it cannot burn in air unless it is in a *very* fine powder. You will thus expect that iron cannot decompose water very easily. Such a thought is quite correct. Iron in fact cannot decompose water unless it is very

strongly heated. The best way of decomposing water by means of iron is to pass steam over red-hot iron filings as follows :—

Take a piece of iron gas pipe about a metre long and fit both ends with good sound corks. Fit each of these corks with a piece of glass tubing about 20 c.m. long. In the middle of the tube pack some small iron nails or iron filings, but do not pack them together so tightly that air or steam cannot easily pass through the pipe.

Put a sand-bath on the tripod stand, and over this a flask containing water. The copper flask in which oxygen was made is a

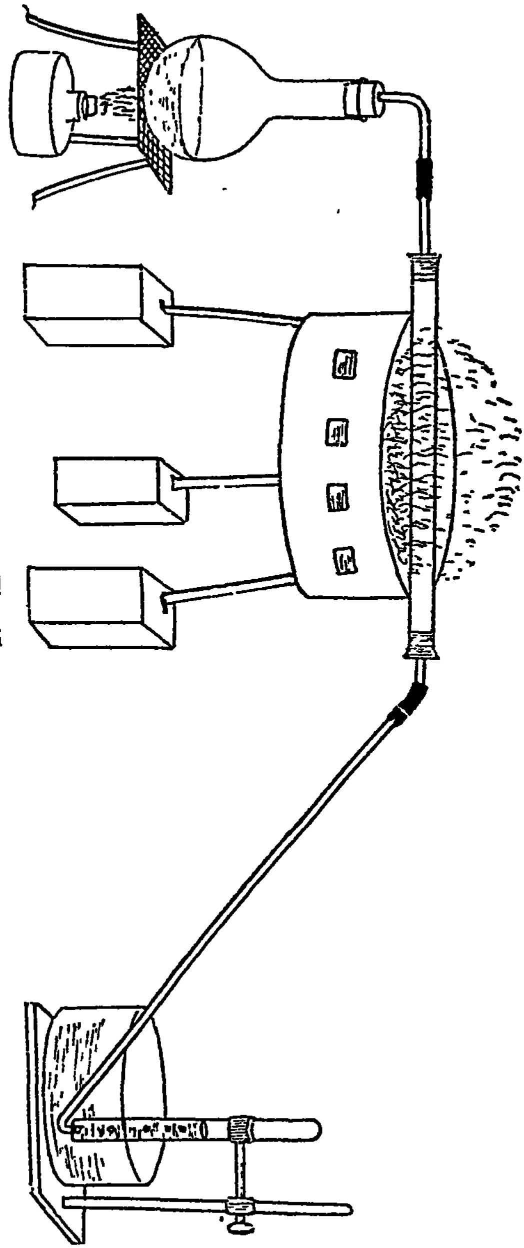


Fig. 45.

very good vessel for this and other experiments where steam is needed, as there is no danger of the copper flask breaking.

Whichever flask you use must be fitted with a cork and bent tube.

Then connect this tube with the iron gas pipe by means of a short rubber tube as shown in figure 45. The gas pipe is supported on a little charcoal stove or *angethi* which can be raised to the required height on bricks.

The other end of the gas pipe is connected to a delivery tube which dips into a *large* trough of water.

When your apparatus is set up, heat up the charcoal stove and fan the fire until the iron pipe is red-hot. Then boil the water in the flask till a current of steam passes over the hot iron filings in the tube. Some steam will pass through the tube without being decomposed but this will condense in the water, and if you have a small vessel of water, the water will soon be made very hot by the steam.

As soon as bubbles of gas begin to be given off, fill a tube with water and collect the gas by displacement. Remember that the pipe was full of air to begin with, as was also the flask, so you will only get air till the steam has been passing for

sometime. Collect one or two tubes of hydrogen by this method. Then remove the delivery tube from the water, and take the spirit lamp from the flask. When you have done this disconnect the gas pipe and put it out of doors to cool.

As soon as the tube is cool, shake out the filings. You will find them covered with a layer of rust, which is like that formed when iron burns in oxygen or rusts in air. This rust is oxide of iron.

Now examine the tubes of hydrogen gas. The gas burns with a blue flame. Mix one tube of hydrogen with a tube of air by holding the two mouth to mouth for a minute and turning them so that first one is on the top and then the other. Set fire to this mixture. There is a slight explosion. The hydrogen combines very readily with the oxygen of the air and this causes the explosion.

Note down the colour and smell of hydrogen.

### XXIV.—HYDROGEN. (2)

*Lecture experiment to be performed by the teacher.*

Action of steam on magnesium.—Magnesium decomposes water much more readily than iron does. Take a piece of magnesium wire and clean it thoroughly by means of a little sand paper. Then put it in a test tube and cover it with water. You

will soon see that tiny bubbles of hydrogen collect on the surface of the magnesium, and after a time the bright appearance of the magnesium is lost and it becomes covered with a film of magnesium oxide.

Steam is even more easily decomposed. It seems strange to say so but magnesium can actually be made to burn in water vapour. Fit up a flask with a cork and bent tube (the flask used in the last experiment). Take a smaller flask and fit it with

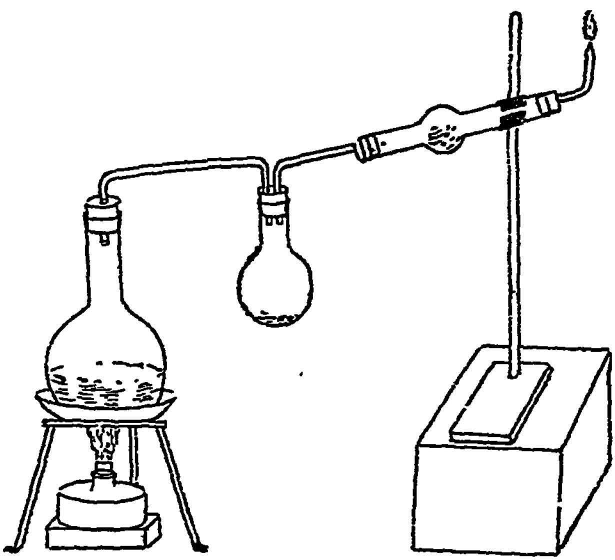


Fig. 46.

a double bored cork and two bent tubes. One of the tubes should be bent at a right angle and the other at an angle of about 100 degrees.

Next get a tube of hard glass and fit it with two corks. Into one of these fix a jet. In the middle of the tube place a few pieces of magnesium ribbon. Then set up the whole apparatus as in the figure. In the large flask water is placed and boiled very gently. The steam passes through the little flask and any water which condenses is collected in it. It is important that no water should condense in the glass tube, so a spirit lamp should be moved along the tube backwards and forwards to keep it quite hot. Then when steam is passing slowly through the apparatus, the part of the tube under the magnesium is strongly heated. It will begin to burn in the steam and the gas which issues at the jet is hydrogen. It will burn if a light is brought near it.

The magnesium is converted into a white powder, exactly like that formed when magnesium burns in air. This is oxide of magnesium.

You have now learned the following :—

**Water on electrolysis gives Hydrogen and Oxygen.**
**Sodium and Water give Oxide of Sodium and Hydrogen.**
**Magnesium and Steam give Oxide of magnesium and Hydrogen.**
**Iron and Steam give Oxide of Iron and Hydrogen.**

You may feel almost sure that water contains only oxygen and hydrogen.

## XXV.—HYDROGEN. (3)

Before you learn any more about the composition of water you must be able to prepare hydrogen by a much easier method than any you have used as yet.

Now all acids contain hydrogen, and in most cases this hydrogen can be easily replaced by a metal in the following way:—

**Hydrochloric acid and Zinc give Zinc chloride and Hydrogen.**—Hydrochloric acid may quite truly be called Hydrogen Chloride, and so you may say—

**Hydrogen chloride** and **Zinc** give **Zinc chloride** and **Hydrogen.** That is very easy to understand.

The simplest method to use for preparing hydrogen is by means of zinc or iron and sulphuric acid, which you may call hydrogen sulphate. Then we have—

**Hydrogen Sulphate and Zinc give Zinc Sulphate and Hydrogen.**

**Hydrogen Sulphate and Iron give Iron Sulphate and Hydrogen.**

Take a wide-mouthed bottle of about half a litre to a litre cubical contents, in its mouth fit a *good* cork.

Now take a thistle funnel and bore the cork at one side to take the funnel and at the other side a short tube bent at a right angle.

Fit a delivery tube to the short bent tube and arrange your apparatus for collecting gas by displacement of water.

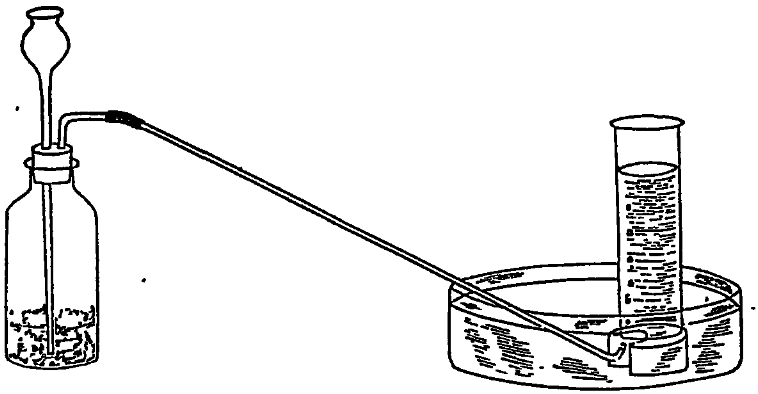


Fig. 47.

Now introduce into the bottle some pieces of granulated zinc until it is about 2 c.m. high in the bottle. Replace the cork and see that the bottom of the funnel reaches almost to the bottom of the bottle.

Next make a little dilute sulphuric acid by pouring 10 c.c. of strong acid into 50 c.c. of water contained in a beaker. Stir with a glass rod while you mix the two liquids. The mixture will become hot. Allow it to cool; you may cool it quickly by allowing the beaker to stand in cold water.

*Note.*—Never pour water into strong sulphuric acid.

When the dilute sulphuric acid is cool pour about 10 c.c. through the thistle funnel on to the zinc. There will be a brisk evolution of hydrogen. The bottle is at first full of air and so the first bubbles which pass through the water are air, then comes air mixed with hydrogen, and lastly pure hydrogen. Collect a tube full of the gas by displacement of water and see whether it burns. If it explodes there is still air present. You must be careful in removing the tubes from the water and in taking them to a light, not to allow any air to get in and mix with hydrogen, so your thumb must not be removed till the tube is close to the flame.

When the gas no longer explodes, but burns with a pale blue flame, collect 4 jars of it. The best way of keeping the hydrogen till you are ready to use it is to put a plate into the vessel of water and slip the jar of hydrogen on to the plate and then remove the two together. Enough water should be removed with the plate to cover the mouth of the jar. The jar should be left standing in the plate of water, of course with the mouth of the jar under water.

Then half fill an empty soda water bottle with water and allow hydrogen to displace the water. It will then be half full of hydrogen and half full of air. Cork it up securely.

Remember that hydrogen is very inflammable and a mixture of air and hydrogen is very explosive. You should never bring a light close to the apparatus while you are collecting hydrogen, especially until all the air has been driven out of the bottle.

Properties of Hydrogen.—Perform the following experiments with the jars of hydrogen which you have prepared :—

1. Take a jar of air and a jar of hydrogen. Hold the jar of hydrogen mouth upwards under the jar of air as in the figure. After half a minute

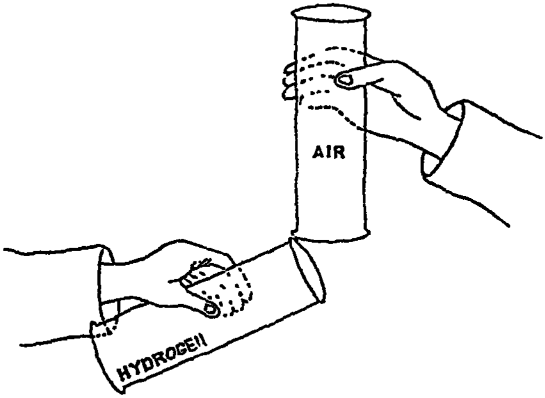



Fig 48.

take the jar which at first contained air and try to light it. There will be a slight explosion showing that hydrogen has gone up into the higher jar. Hydrogen is the lightest of all gases and can be poured upwards.

Fasten a candle to a long wire. Light the candle and push it upwards into a jar of hydrogen. The hydrogen will catch fire and burn, but the candle will be extinguished.

Hydrogen burns but does not support combustion.

3. Is the gas alkaline or acid? Try with litmus.

4. Set fire to a jar and see whether what remains in the jar is acid or alkaline.

5. Now take the soda water bottle containing the mixture of air and hydrogen. Remove the cork and hold the mouth to a spirit lamp. There will be a loud explosion. Be careful that the bottle does not point at any delicate apparatus or any other students.

Hydrogen forms an explosive mixture with air.

**Hydrogen lighter than air.**—The next experiment is a very pretty one and shows the lightness of hydrogen very well.

Make a solution of soap, by dissolving some soap shavings in hot water and adding two or three drops of glycerine. Allow the mixture to stand for 24 hours stirring from time to time. Pour off some of the solution into an evaporating basin.

Attach a long piece of rubber tubing to the hydrogen bottle and to the other end a short clay pipe or thistle funnel.

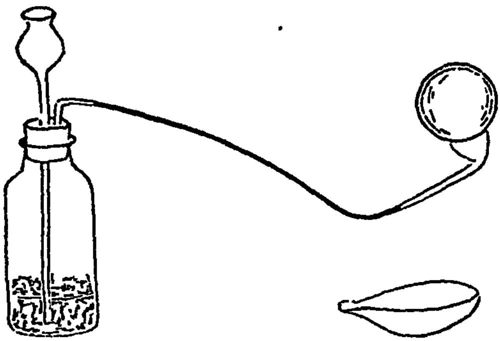


Fig. 49.

Dilute the acid which you used in the last experiment by mixing with half its volume of water so as to make the gas come off more slowly. Then pour on to the zinc and make bubbles of hydrogen by dipping the bow o  the pipe in the soap and then holding it mouth upwards. When the bubble is 2 or 3 inches in diameter a jerk of the pipe will set it free and it will float upwards in the air.

Set fire to a floating bubble with a match, but observe the precautions as on the previous page.

Hydrogen is used for filling large balloons.

Write down in your note book a description of the occurrence, properties and uses of hydrogen, in the way in which the properties of oxygen are described on p. 55.

## XXVI.—HYDROGEN. (4)

**What happens when hydrogen burns in air.**—You have now learned that hydrogen can burn in air, and that a mixture of air and hydrogen explodes when ignited. The object of the next experiment is to find out what is formed in these cases.

Take a piece of glass tubing about 12 inches long. Draw it out into a jet about 3 inches from one end. Then bend the tube at right angles in the middle.

Take the bottle in which you have prepared hydrogen and collect two or three tubes of the gas. When the gas burns with a pale blue flame and does not explode, fix the jet in place of the delivery tube, as shown in the figure.

Then take a dry test tube and lower it over the jet. Hydrogen being very light will fill the tube and force the air out. Remove the tube and place your thumb so as to close it and carry it to the spirit lamp which should be several feet away. If there is any explosion fill the tube again in the

same way, until the hydrogen burns quietly. It is then quite safe to light the hydrogen issuing from the jet and you may do so by means of a match or in any other way.

You now have a jet of hydrogen burning in air. The flame will be somewhat yellow because of the sodium which is in the glass. All compounds of

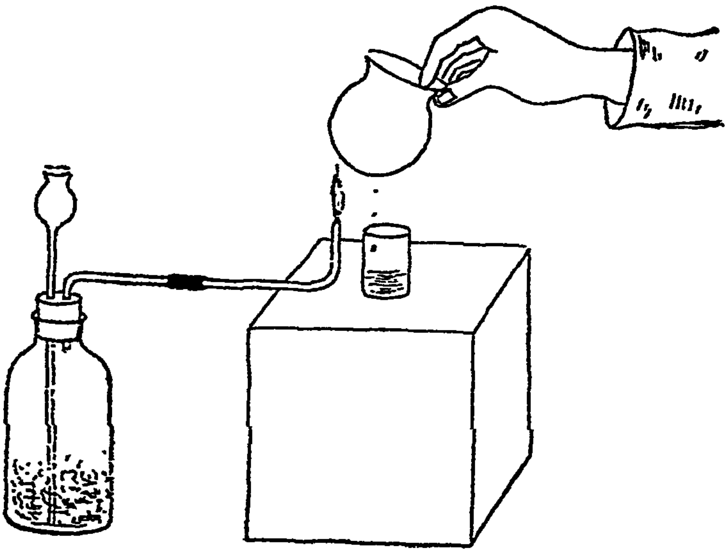


Fig. 50.

sodium colour a flame yellow, as you can easily see by taking a little moist sodium chloride (common salt) on a platinum wire and holding it in the flame of a spirit lamp.

Fill an ordinary well polished brass lotah with cold water. Be careful that the outside is quite dry. Hold it over the flame of burning hydrogen. The brass of the lotah will soon be covered with a dew of tiny drops of liquid; this will form into larger drops which will fall and can be collected in a small dish. This liquid is water. If you can collect enough determine either its freezing or boiling point. Smell and taste the liquid. Examine its action on white anhydrous copper sulphate.

This experiment proves that when hydrogen burns in air, water is formed and consequently also proves that water contains both hydrogen and oxygen.

You cannot yet be *quite* sure that water contains nothing besides these *two* elements. This is the next question you have to answer.

## XXVII.—WATER.

**Composition of water.**—If water is a compound of oxygen and hydrogen and nothing else, hydrogen should combine with oxygen and form water. You have already seen that hydrogen *does* combine with the oxygen of air, but you have *not shown that* there is not some other substance (for instance,

nitrogen) also combined with the hydrogen when it burns in air.

The following experiment has two parts. First, oxygen is made to combine with copper to make oxide of copper; secondly, hydrogen is made to take away this oxygen and leave copper behind. The result of the combination of the oxygen and hydrogen is water. Thus you have a definite proof that water is a compound of oxygen and hydrogen and nothing else.

You may ask whether hydrogen and oxygen cannot combine directly together without the aid of the copper. Yes, they can, but they combine with great violence and the experiment is not a suitable one for school classes.

Preparation of oxide of copper.—Thoroughly clean the iron gas pipe which was used for the preparation of hydrogen from steam. Then pack about 8 inches of the middle of the tube with copper turnings, put it on a charcoal stove and pass a current of oxygen through it. The oxygen is to be prepared in the usual manner by heating potassium chlorate and black oxide of manganese. Keep the middle part of iron tube at a dull red-heat for 15 minutes. Then remove the oxygen apparatus, take the tube out of the stove and allow it to cool.

When it is quite cool shake out some of the copper turnings. They will have become quite black because the oxygen and the copper have combined to form oxide of copper. Put back the copper turnings.

**Preparation of water.**—Now connect the tube with your hydrogen bottle, but between it and the hydrogen bottle put a *wash bottle* containing a little strong sulphuric acid. This acid absorbs water vapour very greedily, and so no water from the dilute acid in the hydrogen bottle can pass over into the iron tube.

It also tells you at what rate the hydrogen is passing by the bubbles passing through the acid. You can regulate the rate by adding more dilute acid slowly to the zinc. If the evolution of gas is much too rapid, add a little water. The wash bottle is simply a bottle with a double bored cork fitted with two bent tubes, one long and one short. The long one passes down below the strong sulphuric acid as in the figure.

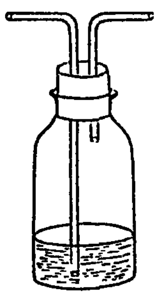


Fig 51

When you have fitted this between the iron pipe and the hydrogen bottle, put a delivery tube on to the end of the iron pipe, and pass a fairly rapid stream of hydrogen through the whole. The iron

pipe may be resting on the stove but of course there must be no fire there until all the air has been expelled from the various parts of the apparatus. Collect a test tube full of gas from time to time, taking care that the hydrogen does not cease to be evolved. When the gas in the tube burns quietly without any explosion, remove the delivery tube and put in its place a bent tube dipping into a small flask as in fig. 52. The flask is kept cold by being immersed in a basin of cold water.

Keep a slow stream of hydrogen passing all the time at such a rate that you can count the bubbles in

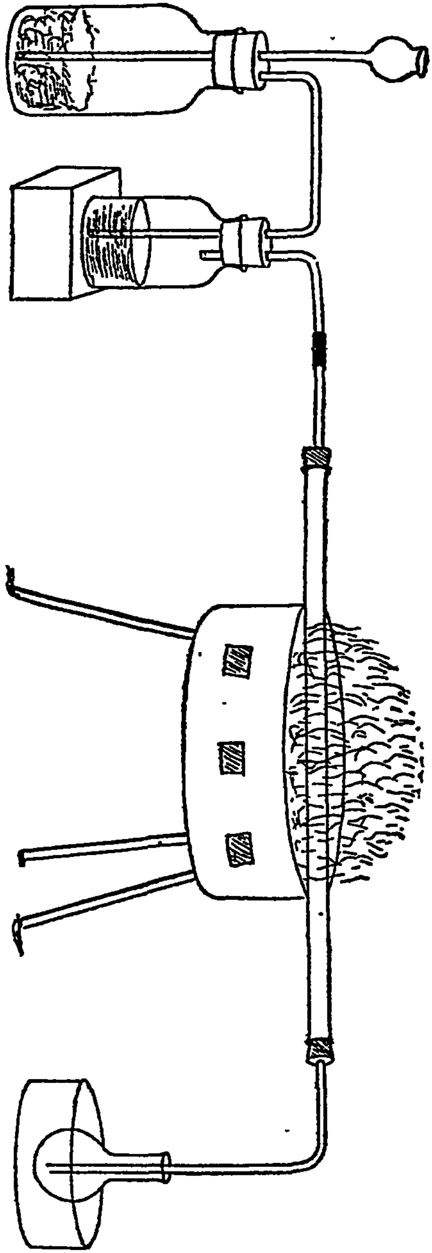


Fig. 52.

the wash bottle. Then heat up the charcoal and make the pipe with the copper oxide red-hot again. Steam will soon pass out into the small flask and condense there to form water. When no more steam comes over, take out the charcoal from the stove, and allow the hydrogen to pass through the tube until it is cool. Then (taking the usual precautions to keep a flame away from the apparatus), remove the hydrogen bottle, and open the tube.

First examine the substance left in the tube. You will find that the black oxide of copper has given up its oxygen to the hydrogen and that copper alone is left.

Then examine the liquid in the flask. Take its boiling-point, taste it, smell it, examine its action on anhydrous sulphate of copper. You find the liquid is water.

You have now definitely proved that water is composed of oxygen and hydrogen, and from the electrolysis experiment you also conclude that water contains two parts by volume of hydrogen to one of oxygen.

## XXVIII.—NATURAL WATERS.

Although perfectly pure water contains nothing but hydrogen and oxygen, most of the water with which you have to deal is not perfectly pure.

The water which you generally use comes from a well or a tank or a river, and neither well water nor tank water nor river water is perfectly pure.

Get some water from any near supply. Pour it out into a beaker. Perhaps it looks quite clear and fresh, but perhaps it looks rather muddy or you may see tiny specks of something or another floating about in it. Such things can be removed by filtering. In all large towns, water from the river is filtered before it passes into the pipes which carry it to different parts of the town. Of course it is not filtered through a funnel and a filter paper, but it passes through large *filter beds* These filter beds consist of layers of fine stone and sand at the bottom of a large tank and the water is made to pass through them. They stop all the solid impurities which float about in the water. From time to time they are cleaned out and fresh stones and sand put in place of that which is taken out and which is often very dirty.

These solid impurities are called suspended impurities.

Besides the suspended impurities there are dissolved impurities. These, as you know, cannot be removed by filtration. They can only be removed by distillation.

**Dissolved Solids.**—To prove that your water contains some dissolved impurities evaporate some down nearly to dryness in a porcelain evaporating dish on a water-bath. Then pour the water from the dish on to a large watch glass and evaporate to complete dryness. You will find a decided residue is left. This is solid matter which was dissolved in the water.

The amount of solids dissolved in river water is very great, and this is carried down into the sea. The Ganges carries away many lakhs of maunds of dissolved solids every year.

Sea water contains about 3½ per cent. of dissolved solid matter most of which is common salt, but there are also compounds of magnesium, calcium and other elements. Rain water is the purest water which occurs in nature. That is because rain water is really distilled water.

Distillation is the condensation of water vapour. Over large areas of water such as the great oceans the air becomes saturated with water vapour. This air passes over the land as wind, and when it reaches a cool place some of the moisture is condensed and

falls as rain. Then this rain takes up solid matter again from the earth, runs down to the sea again in rivers and again is distilled.

According to this the oceans ought to contain more and more dissolved matter every year. This is probably the case, but some of the dissolved matter is deposited in various ways, and is used up as food for shellfish and coral insects and such animals, so the increase is not very large.

Dissolved Gases.—Besides containing solid matter dissolved river water, rain water and in fact nearly all natural waters contain dissolved gases. The most important of these are oxygen and nitrogen, the gases which make up air. There is also a good deal of carbonic acid gas, the gas which is produced when charcoal, coal, wood and many other substances burn in air.

Now gases unlike solids are much less soluble in hot water than they are in cold water, so they can be removed by simply boiling the water.

Take a flask fitted with a cork and delivery tube. The tube passing through the cork must be level with its lower surface. Fill the flask up to the brim with ordinary water and then push in the cork. The water will run into the delivery tube. If much air is left in the tube, remove it and fill it with water by suction. Then close the

lower end of the tube with your finger, refill the flask and again insert the cork.

The flask and tube are now quite full of water. The flask is placed on a sand-bath, or wire gauze, with the end of the delivery tube in a basin of water as in the figure.

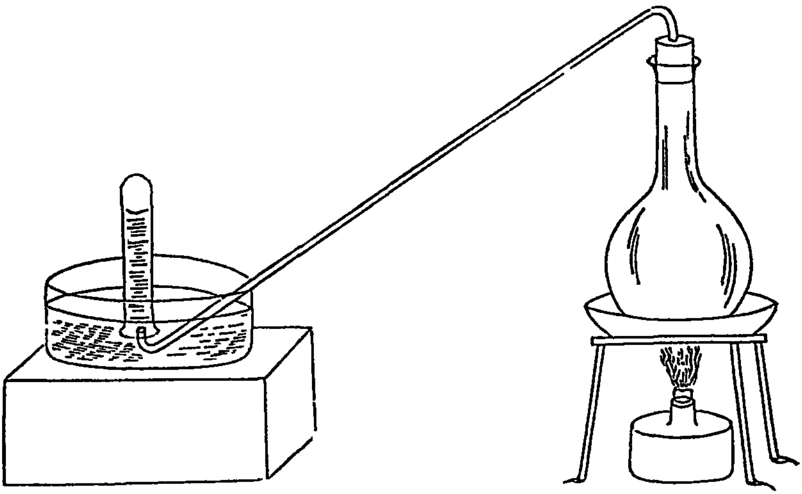


Fig. 53.

Boil the water. Bubbles of gas are soon liberated and these pass through the delivery tube and can be collected by displacement of water as usual.

Collect two tubes of the gas. In one put a little lime-water and shake it up. The lime-water is turned milky. That is because carbonic acid gas is present.

In the other tube put a burning match. It will burn as in ordinary air.

Carbonic acid is very soluble in water. Water will dissolve 20 times as much carbonic acid as it can dissolve of oxygen, and twice as much oxygen as nitrogen. This is very important as you will see later.

## XXIX.—CARBON.

In an earlier lesson you found that when charcoal burned in oxygen a gas was formed which was very different from ordinary air. It turned blue litmus red; and it has many other properties which make it an easy gas to recognize. These we shall soon have to study, but before we pass to this gas, there are a few things to learn about the substance from which it is made.

If you place a small piece of charcoal in a crucible and heat it for a long time, it will burn and by degrees change from a hard black lump into a grey powder or ash. This powder contains many substances, among others lime, carbonate of potash and a little iron rust. But a great deal of the charcoal has burnt away, or as we have now learnt to say, has combined with the oxygen of the

air to form an oxide. The substance which was burnt is **carbon**.

Charcoal is not an element. As you have seen we can break it up and get several different substances out of it. Carbon is an element, and we cannot break it up into any different substances; we can only make it combine with other elements to form compounds.

You may be surprised to hear that carbon in its purest form is one of the most valuable and beautiful things in the world. It exists in glistening, colourless crystals which are called **diamonds**.

If a diamond is very strongly heated in oxygen, it will take fire and burn, the gas which is formed under these circumstances is exactly similar to the gas formed when charcoal burns.

There are several other forms of carbon, but none is so pure as the diamond. Ordinary soot, such as is formed by a smoky lamp, contains a great deal of carbon and so does coal. The "lead" in a lead pencil is really not lead at all, it is **graphite**, and graphite is a fairly pure form of carbon. It is only called lead because the mark which it makes on paper is like the mark made by lead.

Diamonds have been made from graphite, by melting it and allowing the melted graphite to

crystallize very slowly. It needs a very high temperature to melt graphite, more than 3000°, and the diamond crystals are so small that they are not valuable enough to make it worth while to manufacture them in this way.

If you think for a minute, you will see that in one form or another carbon occurs very widely in nature. We have oxygen in air and water, hydrogen in water, nitrogen in air, but carbon is found in all plants and animals. It is true that the carbon is not in the *free* state, as an element; it is always combined, but none the less it is there.

If you place a small piece of wood in a test tube and heat the test tube so as not to set fire to the wood, you will notice that a great many chemical changes occur. First you will notice drops of water form on the sides of the tube; then there will be a darker and oily looking liquid which we call tar, also a gas will be evolved which you can set fire to and which will burn, and lastly, you will find that charcoal is left behind.

This shows that wood contains carbon as well as hydrogen and oxygen. In a similar way you can prove that all vegetable and animal matter contains carbon.

## XXX.—CARBONIC ACID GAS.

When a candle burns in air a gas is formed which turns lime-water milky. This same gas is formed when charcoal burns in oxygen. We call the gas oxide of carbon, or carbonic acid gas.

Carbonic acid gas occurs in many substances, but the commonest is chalk. From chalk, too, is the easiest method of obtaining it in large quantities.

Take some lumps of chalk and put them in a very hot fire. Let them get thoroughly red-hot and remain red-hot for *half* an hour. Then remove them and allow them to cool.

Take a piece of this burnt chalk and put it in a beaker containing a little water. Stir it up well. The water will become warm. Repeat this experiment with chalk in place of the burnt chalk. Nothing happens.

Filter these solutions separately and evaporate part of each of them to dryness in two different dishes. The chalk before burning is not soluble, after burning it is partly soluble in water and the solution leaves a residue on evaporation.

Take a little of each of these solutions in two test tubes and add a few drops of litmus solution

to each. The chalk before burning does not turn the litmus blue, after burning it does.

Heating chalk in this way obviously changes it very much. Let us see what effect heating chalk produces, if we make an arrangement to collect any gases which may be evolved.

Take a clay tobacco pipe* with a long stem and put some small pieces of chalk in the bowl. Close this with a plug of wet clay. To the stem of the pipe attach a piece of glass tubing, and let this dip into a test tube as in the figure.

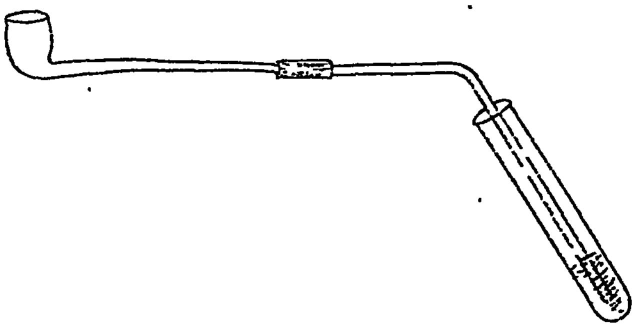


Fig. 54.

Heat the bowl of the pipe to bright redness in a charcoal fire. A gas will soon be given off which turns the lime-water milky.

Dip the tube into a little clean water to wash it, and then pass the gas through some water to which

* If a pipe of this kind is not available, put some chalk into the middle of an iron gas pipe. Close one end completely by means of a cork and heat the middle of the pipe as in lesson XXVII.

a drop or two of litmus has been added. The colour will change to a dull red.

This experiment leads you to think that when chalk is heated a gas is driven off which is the same as that formed when carbon burns in air or oxygen.

The residue left behind when chalk is burnt is called lime so you may write—

Chalk = Lime + Carbonic acid gas.

Chalk is often called carbonate of lime. A more accurate name is carbonate of calcium.

When carbonic acid is passed into lime-water the opposite change takes place and chalk is re-formed, thus—

Lime + Carbonic acid = Chalk, or Carbonate of Calcium.

## XXXI.—CARBONIC ACID GAS.

The carbonic acid gas can be removed from chalk in another and much simpler way.

Carbonic acid is an acid but it is a weak one. If a strong acid is poured over chalk, the strong acid replaces the weak one and the carbonic acid is set free. Thus—

Carbonate of calcium + hydrochloric acid = chloride of calcium + carbonic acid.

Take a bottle or flask, and fit it with a cork carrying a thistle funnel and a bent tube. The bottle which was used for preparing hydrogen will do well. To the bent tube fasten another tube bent at right angles by means of a short rubber tube. The second bent tube must have a long limb as in the figure.

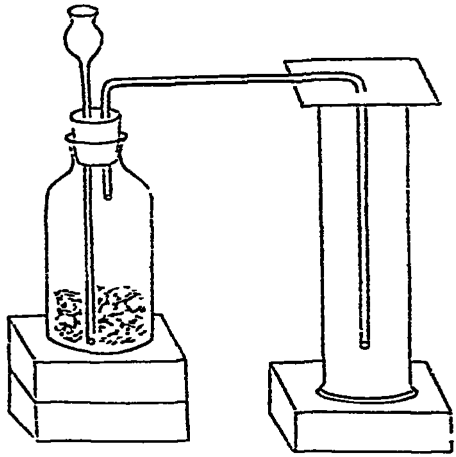


Fig. 55.

The longer limb dips into a jar of air and should nearly reach the bottom of it. The mouth of the jar should be covered with a flat card. This may have a hole in it for the tube to pass through.

If both the bottle and jar are raised above the table on a few bricks, or blocks of wood, it will be very easy to remove the jar of gas when it is full, and replace it by another jar full of air.

Now pour a little dilute hydrochloric acid (one part acid to two parts water) on to the chalk and collect several jars of the gas which is evolved. The gas is very heavy and displaces the air. When the jar is full, the gas will pour over the edges of the jar, just as if it was full of water. You can tell

when this happens by holding a lighted taper under the card, as the gas pours over, it will extinguish the taper.

When you have collected several jars, pour one of them over a lighted candle. It will at once be extinguished.

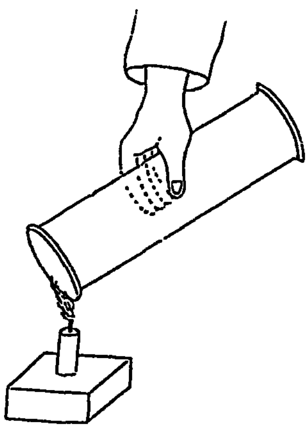


Fig 56

Into a second jar lower a little burning sulphur. This too is extinguished.

In a third pour lime-water, it is at once turned milky.

In a fourth jar pour litmus solution, it is turned dull red. The gas is an acid-forming gas.

In a fifth jar plunge two or three strips of burning magnesium ribbon. The strips of ribbon should be folded together, because a single piece will not burn well in carbonic acid gas. The magnesium burns and takes away the oxygen from the carbon di-oxide, and if you examine the powder which is formed, you will find it contains little particles of black carbon. If you pour some dilute hydrochloric acid on the powder, the white oxide of magnesium will dissolve. Filter the

solution and the black carbon will be left on the paper.

Smell and taste some of the gas.

Carbonic acid is formed—

(1) When a candle, or charcoal, or wood, or anything containing carbon burns in air or oxygen.

(2) When chalk is strongly heated.

(3) When an acid acts upon chalk.

It is a heavy, colourless gas, with no smell and a slightly sweet taste; it does not support combustion, but can be decomposed by brightly burning magnesium to carbon and oxide of magnesium. It dissolves in water to form an acid solution. It can always be recognized by the fact that it turns lime-water milky.

### XXXII.—PLANT AND ANIMAL LIFE.

You have already been told that when animals breathe they take in oxygen from the air, and give out carbonic acid gas. In other words, they are slowly burning away. The burnt portions have to be replaced and they are replaced by the food which animals eat. The way in which this burning goes on is as follows:—

When you draw air into your lungs some of it is absorbed by the blood which dissolves it and

then carries it to all parts of the body. The oxygen which is dissolved combines with some of the carbon in the tissues and forms carbonic acid gas. This is also dissolved in the blood but the blood containing the carbonic acid at last passes back to the lungs again and when you expel the air from your lungs, the carbonic acid is given up by the blood and come out at your mouth.

Take a test tube half full of lime-water and blow air from your lungs into it by means of a glass tube. The lime-water will soon become milky, just as if it had been shaken in a jar of carbonic acid gas.

Now if all animals are continually taking in oxygen from the air and giving back carbonic acid gas in its place it is clear that the air must be getting fuller and fuller of carbonic acid, *unless* there is something at work to remove the carbonic acid and replace the oxygen.

And if the air is becoming full of carbonic acid in place of oxygen, all animal life will cease, and animals will die, because carbonic acid is a poison, and animals cannot live without plenty of oxygen to breathe.

Fortunately for us there is something at work to purify the air again. Let us see what this is.

Take a large beaker full of water and pass carbonic acid into it for a few minutes. Then get some fresh green leaves or water plants; place them at the bottom of the beaker and invert a large funnel over them, taking care that the whole of the funnel is under water. Over the inverted funnel place an inverted tube full of water, as in the illustration.

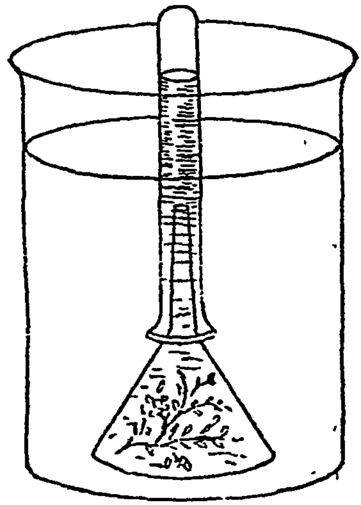


Fig. 57.

Then put the beaker and its contents out into bright sunshine and leave it. In an hour or two you will find that some bubbles of gas have collected on the leaves and that some have passed up the funnel into the tube. When a few c.c. of gas have passed into the tube, remove it and carefully introduce a glowing splinter of wood. You will find that the gas is oxygen.

Here, then, is the key to the mystery. Plants take up carbonic acid gas and use it up giving back oxygen.

This is what plants are always doing. Through the pores in their leaves plants breathe in carbonic acid and eat up the carbon and then breathe out

pure oxygen. You can understand now why the amount of carbonic acid in air does not increase, and you see how necessary plants are to animals, and animals to plants. Remember animals take up oxygen and give out carbonic acid; plants take up carbonic-acid and give out oxygen.

In a previous lesson it was mentioned that water can dissolve oxygen and other gases. That is what enables fishes and other animals to live in water. They breathe the dissolved oxygen and give up carbonic acid to the water, just as animals which live on land breathe oxygen and give up carbonic acid to the air.

## XXXIII.—HARD AND SOFT WATERS.

**Soft water.**—If water readily forms a "lather" with good soap it is called soft water. Take a little rain water, or distilled water, and rub a piece of soap in it, or moisten your hands with water and rub the soap between your hands: you will soon get a white foaming "lather" as it is called. All waters which will give this lather are called "**soft**" waters.

**Hard water.**—Now take some soft water and mix it with a little lime-water, about one part of

lime-water to four parts of water. Pass a current of carbonic acid gas through the mixture. Of course the lime-water will turn milky, but continue the current of carbonic acid for a long time and all the milkiness will disappear.

This is what happens. The carbonic acid converts the lime into chalk, then as more carbonic acid is added to the water the chalk dissolves in it. Chalk cannot dissolve in pure water but it dissolves in carbonic acid.

Next take some of this solution and try to make a lather with soap. *You find it very difficult.* The water is now "hard." Hard waters are those which do not readily make a lather with soap.

There are other things besides calcium carbonate which dissolve in water and make it hard. Gypsum or calcium sulphate is one of these substances. Gypsum can only dissolve very little in water, but quite enough to make the water hard. Gypsum needs no carbonic acid to make it dissolve. Take a little finely powdered gypsum and shake it with water filter and try to make a lather as before with the filtrate. You will soon see that the water is hard.

Now water which is hard because calcium carbonate is dissolved in it is different from water which is hard because of dissolved calcium sulphate

in one very important way. The former can be made soft by simply boiling it, but the latter cannot. Consequently water containing gypsum is called **permanently** hard, while that which contains calcium carbonate is called **temporarily** hard. Permanent means "remaining the same," temporarily means "for a short time."

Take some of the water in which you dissolved carbonate of calcium by means of carbonic acid and boil it in a beaker. You notice two things; first, gas is given off as the solution gets hot until at last it begins to boil, secondly, the water becomes milky again.

What happens is very simple. At first when we pass carbonic acid into lime-water we get calcium carbonate or chalk formed; then the chalk dissolves in more carbonic acid. When we heat this solution the carbonic acid is driven away until the chalk can remain dissolved no longer, but is precipitated.

When you have boiled the water for 10 minutes filter it and again boil. If no more chalk is formed try the water again with soap. You will find it much softer than before.

Permanently hard water cannot be made soft by boiling but it can be softened in another way. If you add some ordinary soda, (the proper name

is carbonate of soda) to water which is hard through dissolved gypsum the following change takes place :—

Calcium Sulphate and Sodium carbonate give
Calcium Carbonate (chalk) and Sodium Sulphate.

Try this with the water containing gypsum, filter off the small quantity of chalk that is formed and see whether the filtrate is soft or hard water. Sodium sulphate does not make water hard.

Hard water is not good either for drinking, washing or for use in engines. In engines which have to use hard water the boilers get coated with carbonate and sulphate of calcium, and then they need much more fuel to make the water boil.

## XXXIV.—HARD WATER.

**How to measure the Hardness of water.**—The hardness of water is measured by the amount of soap which is required to make a lather with a given volume of the water. The method is very simple, and you are to use it to compare the hardness of rain water, river water, well water, and tank water. First make a soap solution. Scrape 10 grams from a cake of good soap, so that you have it in fine shavings. Put these into a flask and cover them with a mixture of one part of alcohol to 5 parts

of a distilled water. Warm the flask gently to boiling point and allow it to stand for an hour with constant shaking. When all the soap has dissolved make it up to a litre with water. Then each 100 c.c. contains 1 gram of soap and each cubic centimetre contains 0·01 gram of soap.

Now get a bottle with a good cork and by means of the measure glass introduce 50 c.c. of water.

Fill a burette up to the top mark with the soap solution. Add a few drops too much and adjust the level by means of the tap of the burette, taking care that the *tap* itself is also full of the solution.

*Then place the bottle under the burette and* allow the soap solution to run into the bottle. First allow 1 c.c. to run in and shake the bottle well after you have added it. If no lather is formed in the bottle, add 1 c.c. more and so on till you get a lather. Suppose you get a lather after adding 15 c.c. and did not get one after adding 14 c.c., then you know that between 14 and 15 c.c. is needed. Take another 50 c.c. of water in the cleaned bottle. Read the burette. Add 14 c.c. of soap solution of the water. Then shake well. Then add soap solution drop by drop and shake after each drop. In this way you will get the exact amount of solution required for 50 c.c. of water. Read the burette again.

Repeat this measurement three times and enter in your note book as follows :—

### I.—TAP WATER.

Volume of water taken = 50 c.c.

| | | | | |
|---|---|---|---|---|
| Reading of burette | before experiment | | 0·0 | = 14·7. |
| Ditto | after | „ | 14·7 | |
| Ditto | before | „ | 14·7 | = 14·9. |
| Ditto | after | „ | 29 6 | |
| Ditto | before | „ | 29·6 | = 14·8. |
| Ditto | after | „ | 34·4 | |

mean = 14·8 c.c.

Thus 50 c.c. of water need 14·8 c.c. of soap solution or ·148 grams of soap.

Now repeat the experiment with water from some other source and enter your results in a similar manner.

Then classify the waters in order of hardness.